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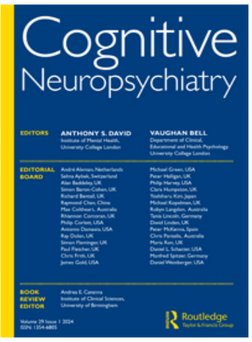

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Non-clinical hallucinations and mental imagery across sensory modalities

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ABSTRACT

Introduction: Vivid mental imagery has been proposed to increase the likelihood of experiencing hallucinations. Typically, studies have employed a modality general approach to mental imagery which compares imagery across multiple domains (e.g., visual, auditory and tactile) to hallucinations in multiple senses. However, modality specific imagery may be a better predictor of hallucinations in the same domain. The study examined the contribution of imagery to hallucinations in a non-clinical sample and specifically whether imagery best predicted hallucinations at a modality general or modality specific level.

Methods: In study one, modality general and modality specific accounts of the imagery-hallucination relationship were contrasted through application of self-report measures in a sample of 434 students. Study two used a subsample ($n = 103$) to extend exploration of the imagery-hallucinations relationship using a performance-based imagery task.

Results: A small to moderate modality general relationship was observed between self-report imagery and hallucination proneness. There was only evidence of a modality specific relationship in the tactile domain. Performance-based imagery measures were unrelated to hallucinations and self-report imagery.

Conclusions: Mental imagery may act as a modality general process increasing hallucination proneness. The observed distinction between self-report and performance-based imagery highlights the difficulty of accurately measuring internal processes.

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Hallucinations; imagery; psychosis

Introduction

Auditory hallucinations are reported by around 60–80% of individuals with psychosis (de Leede-Smith & Barkus, 2013). However, they are not uncommon in non-clinical participants whom also report auditory hallucinations. Lifetime prevalence estimates of around

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7% (McGrath et al., 2015) are reported, but they can be much more commonly reported (see Linszen et al., 2022).

For people with psychosis there has been an understandable focus on auditory hallucinations given their prevalence and impact (Sheaves et al., 2023). However, increasingly the importance of hallucinations in other sensory modalities is recognised. In two clinical samples, McCarthy-Jones et al. (2017) found a range of modalities reported across the lifetime; 64–80% auditory, 23–31% visual, 9–19% tactile and 6–10% olfactory. In people with psychosis there is a characteristic pattern of auditory being more common than visual hallucinations, which are more common than hallucinations in other sensory modalities (Toh et al., 2020). However, whilst non-clinical participants also report a range of unusual sensory experiences it seems that auditory and visual experiences are reported to a similar degree (Toh et al., 2020).

What leads people to see and hear things is complex, but one hypothesis is that individuals who hallucinate more frequently attribute internally generated phenomena to external sources (Waters et al., 2012; though, see Moseley et al., 2021, 2022). This bias may reflect a difference in reality monitoring which is an individual's ability to discriminate between memories derived from perception and mental content generated by thought, imagination and dreams (Johnson & Raye, 1981). It is possible individuals are generating internal representations that are as intense and specific as externally provided stimuli leading the reality monitoring system to interpret them as occurring externally (Fazekas, 2021). Such an explanation has parallels with theoretical models in the context of both Parkinson's disease (Collerton et al., 2023; Shine et al., 2014) and Charles Bonnet syndrome (Reichert et al., 2013). Here it is suggested that, in the absence of high-quality visual input, unconstrained default network activity dominates the perceptual processes through enhanced reliance on perceptual predictions in the form of mental imagery. Together this suggests that a general proneness to unconstrained or heightened mental imagery may lead the reality monitoring system to misperceive internally generated phenomena as happening externally.

Mental imagery is (like hallucinations) characterised by percept-like experiences occurring without external sensory input (Kosslyn et al., 2001) and is associated with an increase in related sensory brain area activity (Slotnick et al., 2005). Such similarities have led to the proposal of imagery as a candidate mechanism underpinning hallucinations (Nanay, 2016) (although imagery is associated with a degree of perceived control, unlike hallucinations). Further, like hallucinations, imagery vividness also varies between individuals (Ji et al., 2019) and across sensory modalities (Andrade et al., 2014). For instance, while vivid mental images were observed in all domains, they are typically most vivid in the auditory and visual domains (Andrade et al., 2014). Hence, mental imagery, like hallucination proneness, is dominated by the visual and auditory domains. That noted, in most studies it is visual (rather than auditory) imagery which is reported as most vivid (Andrade et al., 2014).

To date, findings investigating the relationship between imagery and hallucination proneness in non-neurologically impaired individuals have been mixed. Some studies suggest that individuals who score highly on measures of hallucination proneness report greater imagery vividness (Aynsworth et al., 2017; Barrett, 1993). However, others find no significant relationship between imagery vividness and hallucinations (Auvinen-Lintunen et al., 2022; Böcker et al., 2000). What is less clear is whether there is a modality specific relationship between mental imagery and hallucinations (e.g., auditory imagery is specifically associated with auditory hallucinations) or whether there is a modality-general relationship where multiple sensory modalities are affected simultaneously (e.g., differences in one general process increase the likelihood of all types of hallucination; Fernyhough, 2019). Commonly, studies report relationships between general measures of hallucination proneness and domain non-specific imagery questionnaires (e.g., Spontaneous Use of Imagery Scale; Kosslyn et al., 1998) or visual imagery measures (e.g., Vividness of Mental Imagery Questionnaire; Marks, 1973). Such comparisons do not allow for the possibility that imagery and hallucinations have a modality-specific relationship.

Importantly, many of these studies employ only self-report measures of imagery (e.g., Auvinen-Lintunen et al., 2022; Aynsworth et al., 2017). Self-report and performance-based measures of imagery have been found to differ (Aleman & de Haan, 2004; Lequerica et al., 2002). Aleman et al. (1999) found hallucination prone individuals reported more vivid mental imagery but showed poorer performance on a performance-based task of imagery inspection. Consequently, in their comprehensive review, Pearson et al. (2013) recommend studies exploring imagery employ both self-report and performance-based measures.

The present report consists of two studies that examined the contribution of imagery to hallucinations in a non-clinical sample. Study one employed self-report measures of hallucination proneness (i.e., Multi-modality Sensory Experiences Questionnaire**,** Mitchell et al., 2017**)** and imagery (i.e., The Plymouth Sensory Imagery Questionnaire, Andrade et al., 2014). These measures assessed both general and modality specific imagery and hallucinations allowing exploration of both modality general and modality specific accounts of the hallucination-imagery relationship. Study two further explored the relationship between imagery and hallucination proneness by incorporating performance-based imagery measures (adapted from Noordzij et al., 2007).

Study one

Based on previous literature and theory (Aleman et al., 1999; Aynsworth et al., 2017; Fazekas, 2021; Nanay, 2016) the first hypothesis was that modality-general hallucination proneness would be associated with more vivid imagery. The second hypothesis was that domain congruent imagery would be more strongly related to hallucination proneness than domain incongruent imagery (e.g., visual hallucinations would be more strongly related to visual imagery than non-visual imagery).

Method

Participants

509 participants were recruited from two universities via an online survey. Three participants were removed owing to a combination of unusually fast responses and consistently answering towards the survey extremes. A further participant was removed as their age (71) was markedly different (> 3 standard deviations) from the other participants meaning 505 participants were retained. Of these, 434 completed both the hallucinations measure and the measure of mental imagery and were included in the analyses. Participant's ages ranged from 18 to 50 years (M = 21.24, SD = 4.94). Most were female (*n* = 335/434, 77%), with male (*n* = 78, 18%), non-binary (*n* = 13, 3%) and other/non-disclosed (*n* = 8,

1.8%) individuals completing the sample. Most participants were White British ($n = 315$ 72%; further demographic information is available in supplementary table S1).

Measures

Multi-modality Sensory Experiences Questionnaire (MUSE-Q) (Mitchell et al., 2017). The MUSE-Q is a 43 item self-report scale assessing unusual sensory experiences across six modalities (visual, auditory, olfactory, gustatory, bodily sensations and sensed presence). Higher scores represent greater reporting of hallucinatory experiences. The measure has been validated in both clinical and non-clinical populations. In this sample the internal consistency was excellent ($\alpha = 0.950$)

Plymouth Sensory Imagery Questionnaire Short Form (PsiQ-SF) (Andrade et al., 2014). The PsiQ-SF is a 21-question measure consisting of seven sets of three items asking participants to imagine sensory experiences in different domains (vision, sound, smell, taste, touch, bodily sensation and emotional feeling) and report the relative strength on a 1 (no image at all) to 7 (as vivid as real life) scale. The scale has been validated in a similar non-clinical population. In this sample the internal consistency was excellent ($\alpha = 0.948$)

Procedure

Participants were recruited via email, posters, presentations in lectures and accessed the online questionnaires through Qualtrics. Informed consent was obtained electronically prior to testing. Participants completed the MUSE-Q and PsiQ-SF.

Sample size considerations

Given hallucination (auditory and visual) prevalence estimates of around 7% in non-clinical populations (Aynsworth et al., 2023; McGrath et al., 2015) an initial sample size of >500 people was targeted to ensure a meaningful proportion of participants would report clinical like hallucinations. Further, it was anticipated that this sample size would support recruitment for Study Two which required a representative range of experiences.

Ethical considerations

The project was subject to independent peer review, and ethical approval for both studies was obtained from a Newcastle University Ethics committee. Participants gave full informed consent. The authors abided by the Ethical Principals of Psychologists Code of Conduct as set out by the HCPC and BPS.

Results

Data preparation

MUSE-Q and PSIQ subscales alongside full scale scores were tested for normality using Shapiro–Wilk. All variables excluding PSIQ total score, $W(434) = 0.994$, $p = 0.118$, were non-normally distributed ($p < 0.001$). Square root and log transformations did not correct the non-normality. Consequently, non-parametric analyses were undertaken.

The MUSE-Q overall score was compared to the original MUSE-Q data (Mitchell et al., 2017) using a one-sample Wilcoxon signed rank test. The current sample reported significantly higher MUSE-Q scores (Mdn = 56, N = 434), than the sample in Mitchell et al. (2017) (Mdn = 47, $N = 514$, $Z = 6.669$, $p < 0.001$).

MUSE-Q and PSIQ summary data is detailed in Table 1 below. As expected, auditory and visual unusual sensory experiences were commonly reported. Tactile experiences were also very common. Similarly, auditory, visual and tactile imagery alongside bodily imagery were reported as most vivid.

Relationship between self-report imagery and hallucinations

A Spearman correlation indicated a small-moderate, significant positive correlation between the MUSE-Q and PSIQ full scale scores ($r(434) = 0.265$, $p < 0.001$ CI .173–.353). The analysis was repeated including only the five core sensory modalities. Sensed presence was removed as it is not always considered a hallucinatory experience (Lim et al., 2016; Toh et al., 2020) and testing modality specific congruence was not possible as there was no equivalent in the imagery measure. This analysis remained significant ($r(434) = 0.266$, $p < 0.001$ CI.174–.354).

Upon review of the MUSE-Q, five of the items (supplementary table S2) assessed perceived voluntary control of experience which is closer to the definition of imagery than hallucinations. This overlap of content between the two measures could have artificially inflated the relationship between imagery and hallucinations, hence to reduce this potential confound these items were removed and the Spearman's rank correlation was recomputed. The relationship remained significant $r(434) = 0.231$, $p < 0.001$ CI .137–.353 These findings indicate a modest modality general relationship between imagery and hallucinations.

To test the modality-specificity of this relationship an asymptotic z-test based on Steiger's equations 3 and 10 (Lee & Preacher, 2013) was employed. Once again, the sensed presence subscale was excluded from this analysis. Therefore, the five subscales (visual, auditory, olfactory, gustatory and tactile) for the PSIQ and MUSE-Q were included in this analysis.

The analysis compared domain congruent correlations (e.g., visual hallucinations and visual imagery) to domain incongruent correlations (e.g., mean correlation between

Table 1. MUSE-Q and PSIQ scales.

Modality	MUSE-Q			PSIQ		
	Max Score	Mean (sd)	Median	Max Score	Mean (sd)	Median
Auditory	28	13.56 (5.95)	13	21	13.77 (4.32)	14
Visual	32	11.97 (7.01)	11	21	13.76 (4.39)	14
Olfactory	32	8.09 (6.51)	7	21	9.56 (4.68)	9
Gustatory	32	8.50 (6.52)	8	21	10.01 (4.81)	10
Tactile	32	12.25 (8.03)	11	21	12.82 (4.86)	13
SP	16	3.99 (3.59)	3			
Body Sense				21	12.99 (4.54)	13
Feeling				21	12.98 (4.89)	14
Total	172	58.37 (30.19)	56	147	85.9 (25.43)	86

Abbreviations: SP, Sensed Presence.

visual hallucinations and auditory/olfactory/gustatory/tactile imagery). Table 2 displays correlations between the MUSE-Q and PSIQ.

Initially the full subscales for each analysis were used. All correlations were stronger for domain congruent pairings but only the olfactory ($Z = 2.023$, $p = 0.043$) and tactile ($Z = 2.201$, $p = 0.028$) domains reached the threshold for significance. To exclude the impact of MUSE-Q voluntary control items the analysis was repeated using the revised version of the subscale. For this analysis, all correlations excluding the visual domain ($Z = -0.374$, $p = 0.709$) were in the expected direction but only the tactile domain remained significant ($Z = 2.127$, $p = 0.033$). Consequently, there was some evidence that tactile imagery was more closely associated with tactile unusual sensory experiences when compared to other imagery types.

Discussion

The non-clinical participants in this study reported a range of hallucinatory experiences across a number of sensory domains demonstrating that a focus solely on auditory experiences risks neglecting a person's actual experience. When exploring the contribution of imagery to the range of these hallucinatory experiences there was a modality general relationship between mental imagery and multi-sensory hallucinations, supporting hypothesis one. Partially supporting hypothesis two, tactile imagery was found to have a modality specific impact on tactile hallucinations. However, there was no evidence of a modality specific relationship in any other domain particularly once the voluntary control items were removed.

Study two

Introduction

The first study showed that heightened imagery contributed to increased reporting of hallucinatory experiences (Aleman et al., 1999). A modality specific relationship was only observed in the tactile domain, implying a weak modality specific contribution of imagery to hallucinations. However, the findings require replication on an imagery measure not based on self-report. Consequently, study two examined the contribution of imagery to hallucinations, using a performance-based measure.

Research on other constructs such as cognitive empathy (Murphy & Lilienfeld, 2019) and self-control (Saunders et al., 2018) also reveals differences between self-report and performance-based tasks. Dang et al. (2020) reference Hedge et al.'s (2018) reliability paradox which notes that experimental tasks are typically designed to prioritise within participant variability at the expense of between-participant differences. As between participants variability is in the numerator for reliability, lower between-person variability reduces the reliability of behavioural measures. Thus, observed differences between the measurement modalities are often driven by poor reliability of the performance-based task.

In the first study, the PSIQ (self-report) measure demonstrated excellent internal consistency. Studies of "objective" tasks in the field of hallucinations such as auditory self-recognition tasks have unacceptably low levels of reliability (Smailes et al., 2022). Hence, in study two, there is particular consideration of measure reliability.

Table 2. MUSE-Q and PSIQ subscale correlations ($n = 434$).

MUSE-Q	Auditory		Visual		Olfactory		Gustatory		Tactile	
PSIQ	FSS	IIR	FSS	IIR	FSS	IIR	FSS	IIR	FSS	IIR
Auditory	.168**	.132**	.184**	.148**	.068	.027	.141**	.117*	.142**	.138**
Visual	.148**	.113**	.182**	.131**	.101*	.069	.126**	.110*	.149**	.139**
Olfactory	.133**	.128**	.172**	.152**	.218**	.175**	.200**	.178**	.136**	.130**
Gustatory	.105*	.088	.150**	.120*	.161**	.118*	.194**	.163**	.117*	.110**
Tactile	.174**	.150**	.213**	.177**	.181**	.136**	.195**	.172**	.230**	.220**

Abbreviations: FSS, Full Subscale; IIR, Imagery Item Removed. $^{**}p < 0.01$, $^{*}p < 0.05$.

As with study one, it was predicted that modality-general hallucination proneness would be associated with more vivid imagery. The second hypothesis was that modality congruent imagery would be more strongly related to hallucination proneness than modality incongruent imagery. Finally, despite some findings suggesting a dissociation between self-report and performance-based imagery (e.g., Aleman et al., 1999) the third hypothesis was that there would be a significant positive relationship between self-report and performance-based imagery tasks.

Method

Participants

Participants for study two were recruited based on their MUSE-Q scores in study one. Eligible participants were contacted within a month of completing study one. Recruitment aimed to involve people with a wide range of unusual experiences. The mean ($M = 50.5$) and SD (29.94) from the Mitchell (2017) paper were used to calculate four quartiles each containing 25% of the sample. A total of 107 participants were recruited. However, four participants were excluded, two owing to incomplete survey responses and two owing to obvious distraction during task administration. Hence, 103 participants were included in the analysis representing the quartiles (low score 0–30 $n = 20$; mid-low score 31–50 $n = 27$; mid to high scores 51–70 $n = 24$; and high scores 71–172 $n = 32$). Participant's ages ranged from 18 to 46 years ($M = 22.16$, SD = 5.48). Most participants were female ($n = 75$, 72.8%) with the remainder of the sample comprising male ($n = 24$, 23.3%) and other ($n = 4$, 3.9%). Most participants were White British ($n = 66$, 64.2%; see supplementary table S1 for further demographic information).

Measures

Visual Form Imagery Task (amended) (VIT) (Noordzij et al., 2007). The VIT assesses visual imagery generation. The original task presents participants with 23 triads of common objects (as words) and asks them to determine the odd one out based upon shape. For example, if "book", "ball" and "shoe box" were presented the deviant item would be "ball". The aim of the task is to require participants to engage in visual imagery when determining the odd one out. The measure was piloted on seven male participants (Age, $M = 25$, SD = 0.535) and reduced to 20 items following feedback regarding the ease of imagery of the items involved in the triads.

Auditory Imagery Task (amended) (AIT) (Noordzij et al., 2007) – The AIT assesses auditory imagery generation. The original task presents participants with 23 triads of common sounds (as words) and asks them to determine the odd one out based upon sound. For example, if "tractor", "blender" and "whistle" were presented the deviant item would be "whistle". As with the VIT, the aim of the task is to require participants to engage in auditory imagery when determining the odd one out. The measure was piloted on the same seven male participants and reduced to 20 items following feedback.

Multi-modality Sensory Experiences Questionnaire (MUSE-Q) (Mitchell et al., 2017) – This is described in study one, although only the visual and auditory subscales were used in Study Two. The auditory ($\alpha = 0.836$) and visual ($\alpha = 0.863$) subscales demonstrated good internal consistency.

Plymouth Sensory Imagery Questionnaire Short Form (PsiQ-SF) (Andrade et al., 2014) – This was described in study one. For this sample, the PSIQ (α = 0.948) demonstrated excellent internal consistency.

Moderately strong test-retest reliability was demonstrated for all scales; Auditory MUSE-Q $r(103) = 0.741$, $p < 0.001$ CI .634–.820, Visual MUSE-Q, $r(103) = 0.787$, $p < 0.001$ CI .695–.853 and PSIQ, $r(103) = 0.841$, $p < 0.001$ CI .767–.892.

Procedure

Consenting study one participants were contacted by email and provided with an information sheet detailing study two. Participants completed an online consent form then the PSIQ and MUSE-Q subscales via Qualtrics and booked a time to complete the imagery tasks via Microsoft Teams. For this session the experimenter was present, and the participants were asked to confirm their environment was free from distraction. The VIT and AIT were administered in a counterbalanced order. Participants were asked to keep their cameras on throughout. Upon completion participants received a verbal and written debrief. Participants were compensated with either research credits or prize draw entry.

Sample size considerations

An a-priori power analysis was completed to determine the sample size required to detect differences in correlation strength between domain congruent correlations (e.g., visual imagery and visual hallucinations) and domain incongruent correlations (e.g., auditory imagery and visual hallucinations). Owing to the paucity of research exploring the relationship between performance-based tasks of imagery and hallucinations sample size calculations were based upon observing a difference of $r = 0.4$ (domain congruent) vs $r = 0.2$ (domain incongruent); a difference in variance of 16% vs 4%. Validation of the PSIQ estimated a correlation of $r = 0.56$ between visual and auditory imagery (Andrade et al., 2014), this value was used as the common index. Using these values at a significance level of 0.05 a total of 120 participants were required to achieve a power of 0.8 when using an asymptotic z-test to test the difference in strength of two dependent correlations (G*Power, Faul et al., 2007).

Results

Missing data and data preparation

Analysis of missing data was conducted for each questionnaire measure using Littles MCAR test (Little, 1988). Data was determined to be missing at random for all scales; Auditory MUSE $\chi2$ (18) = 23.375, $p = 0.177$, Visual MUSE $\chi2$ (14) = 9.709, $p = 0.783$, PSIQ $\chi2$ (127) = 98.065, $p = 0.973$. Multiple imputation was applied to generate values for missing data in all MUSE-Q and PSIQ subscales along with PSIQ full scale scores. 5 imputations were generated, and pooled values were used in the reported analysis.

Scores on both performance-based measures are reported in Table 3. Participants generally performed well making few errors, with performance slightly better on the visual task.

All variables were tested for normality using Shapiro–Wilk. All variables excluding the original MUSE-Q visual variable W(103) = 0.961, $p = 0.004$ were normally distributed ($p > 0.05$); consequently, non-parametric correlations were reported for analyses containing the visual MUSE-Q variable.

VIT and AIT data was tested for normality, neither the VIT data W(103) = 0.908, $p < 0.001$ nor the AIT data W(103) = 0.938, $p < 0.001$ was normally distributed. Review of histograms indicated this was driven by negative skew; square root and log transformations did not correct this. Consequently, non-parametric correlations were reported.

No significant relationship was observed between the total score of both performance-based tasks and the study one MUSE-Q overall score $r(103) = 0.015$ $p = 0.884$ CI −.185–.213. Similarly, there was no relationship between the VIT and the study two MUSE-Q visual subscale $r(103) = 0.033$, $p = 0.742$ CI −.169–.233 or the AIT and the study two MUSE-Q auditory subscale $r(103) = 0.004$, $p = 0.966$ CI −.198–.206.

Hence, there was no relationship between imagery and hallucinations in general, and no modality specificity. Similarly, there was no significant relationship between AIT and PSIQ-auditory $r(103) = -0.003$, $p = 0.979$ CI −.198–.203, or between VIT and PSIQ-visual $r(103) = -.069$, $p = 0.490$ CI −.267–.133.

Split half reliability for the AIT and VIT was calculated using the RElex tool (Steinke & Kopp, 2020). Split half parallel reliability values are reported based on the Spearman–Brown formula (Spearman, 1910), both analyses used 5000 iterations. The VIT split half reliability analysis revealed a median reliability coefficient of $P_{sp} = 0.59$ (95%CI 0.44–0.70) and the AIT split half reliability revealed a median reliability coefficient of $P_{sp} = 0.48$ (95% CI 0.33–0.63). Neither task reached the minimum acceptable threshold to be considered reliable ($\alpha = 0.6–0.7$) (Ursachi et al., 2015).

Discussion

In study two there was no support for the hypotheses. In contrast to study one there was no association between hallucination frequency and mental imagery as assessed by performance-based tasks, either generally or specifically between auditory imagery and auditory hallucinations (or for visual imagery and experiences). Further, contrary to the third hypothesis there was no relationship between the self-report imagery measure and performance-based imagery tasks. This could be owing to the weak internal consistency of the performance-based tasks.

General discussion

Both studies explored the relationship between imagery and hallucinations. In study one a self-report imagery measure provided evidence of a small but significant relationship between modality general imagery and hallucinations, supporting the first hypothesis.

Table 3. Performance based imagery tasks.

Modality (Max Score)	Mean (sd)	Median
Visual (20)	15.97 (2.49)	16
Auditory (20)	13.01 (2.43)	13
Total (40)	28.98 (3.62)	30

However, there was an absence of a modality specific imagery and hallucinations relationship in all domains excluding tactile. Consequently, imagery appeared best understood as a modality general process leading to a general increase in hallucination proneness, though tactile imagery may be an exception.

Exploration of the relationship between imagery and hallucinations was extended in study two through incorporation of an auditory and a visual performance-based imagery task. It was striking that there was no relationship between either imagery task and domain congruent, or overall hallucination proneness. There was also no association between the self-report and performance-based measures. This is consistent with Aleman et al. (1999), who also reported a difference between self-report and performance-based imagery in hallucinations. Further research should aim to understand the constructs being assessed by both self-report and performance-based measures of imagery – it could be, for example, that this research area commits the "jingle fallacy", in which two measures are assumed to measure the same construct simply because they share the same name (Flake & Fried, 2020).

For instance, it is possible that some participants applied non-imagery-based strategies for the performance-based task. For example, in some image inspection tasks, differentiating between imagery inspection and semantic knowledge of stimuli is problematic (Pearson et al., 2013; Pylyshyn, 2002). Hence participants may have used semantic knowledge to determine their answers (e.g., a smart phone is rectangular, a ruler is rectangular and a ball is spherical). In future studies such strategies may be partly controlled for through the application of measures such as a visualiser verbaliser questionnaire (Kozhevnikov et al., 2005).

An alternative approach would be to use imagery-based tasks where use of alternative strategies is highly improbable. Policardi et al. (1996) describe a comprehensive battery of visual tasks which would offer a more thorough assessment of visual mental imagery. Other visual imagery tasks that might be suitable include the Image Maintenance Task (Kosslyn et al., 1990) and the Visual Patterns Test (Della Sala et al., 1999) though it is worth noting that most visual tasks are without the auditory counterpart that our design required.

Furthermore, even assuming an imagery-based strategy, participants must hold multiple items in working memory. While our student population implies that profound working memory deficits are unlikely, the absence of a working memory measure means we cannot evaluate its possible confounding effect. Thus, future studies may seek to include a measure of working memory such as the digit span. Alternatively, as raised above, poor reliability of performance-based tasks may have led to low statistical power in the analyses using these tasks.

It is possible that the results of the performance-based task represent the true extent of any association between imagery and hallucination proneness. However, the observed difference between self-report and objective measures reflects the challenge of accurately measuring internal processes. Given the poor internal reliability of the performance-based measure, it may make sense to err towards the self-report findings.

Additional limitations include the sensitive measure of hallucinations. This had the effect of capturing many relevant experiences but may reduce comparability to clinical hallucinations. Consequently, the findings require reproduction in a clinical sample with current hallucinations.

Overall, study one demonstrated a modality general relationship between self-report imagery and hallucination proneness. However, only tactile imagery showed evidence of a modality specific relationship. Further, there was no relationship between domain congruent hallucinations and the performance-based imagery tasks. Finally, self-report and performance-based imagery measures were found to be unrelated. This dissociation was likely influenced by poor reliability, potentially driven by little between-subjects variation.

In terms of theoretical implications, it would seem there is some support for a modality general understanding of hallucinatory experiences, at least in non-clinical participants. This would also be consistent with the similar rate of reporting of auditory and visual experiences, which is not the case with clinical participants (Toh et al., 2020).

Clearly given the non-clinical sample clinical implications are limited. However, the apparent role of imagery in contributing to hallucinatory experiences does encourage consideration of utilising this as a possible treatment resource (Dudley et al., 2011). Where people regard a process as a strength it can be utilised as a method for overcoming or managing one's issues. Further, imagery transformation approaches have been helpful in dealing with a range of emotional issues (Holmes & Mathews, 2010) and specifically for distressing voices (Ison et al., 2014) nightmares (Sheaves et al., 2015) and persecutory ideation (Taylor et al., 2019).

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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RD receives payment for workshops in treating hallucinations and grant funding investigating psychological therapies for psychosis. DC receives royalties on books on hallucinations. RD and CA were supported by the North East and North Cumbria NIHR ARC fellowship funding to help support mental health research.

Data availability statement

Summary and anonymised data have been made publicly available via OSF and can be accessed at https://osf.io/pys8h/.

Notes on contributors

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References

Aleman, A., Böcker, K. B., & de Haan, E. H. (1999). Disposition towards hallucination and subjective versus objective vividness of imagery in normal subjects. *Personality and Individual Differences*, *27*(4), 707–714. https://doi.org/10.1016/S0191-8869(98)00270-0

Aleman, A., & de Haan, E. H. (2004). Fantasy proneness, mental imagery and reality monitoring. *Personality and Individual Differences*, *36*(8), 1747–1754. https://doi.org/10.1016/j.paid.2003.07.011

Andrade, J., May, J., Deeprose, C., Baugh, S. J., & Ganis, G. (2014). Assessing vividness of mental imagery: The Plymouth Sensory Imagery Questionnaire. *British Journal of Psychology*, *105*(4), 547–563. https://doi.org/10.1111/bjop.12050

Auvinen-Lintunen, L., Ilonen, T., Kieseppä, T., Suvisaari, J., & Lindgren, M. (2022). Mental imagery in early psychosis. *Imagination, Cognition and Personality*, *41*(3), 299–322. https://doi.org/10.1177/02762366211021762

Aynsworth, C., Nemat, N., Collerton, D., Smailes, D., & Dudley, R. (2017). Reality monitoring performance and the role of visual imagery in visual hallucinations. *Behaviour Research and Therapy*, *97*, 115–122. https://doi.org/10.1016/j.brat.2017.07.012

Aynsworth, C., Rolinson, J., Pervez, M., Collerton, D., & Dudley, R. (2023). What is the frequency and nature of visual hallucinations in non-clinical participants? *Psychology and Psychotherapy, Theory, Research and Practice*, *96*(2), 281–295. https://doi.org/10.1111/papt.12440

Barrett, T. R. (1993). Verbal hallucinations in normals—II: Self-reported imagery vividness. *Personality and Individual Differences*, *15*(1), 61–67. https://doi.org/10.1016/0191-8869(93)90041-Z

Böcker, K. B., Hijman, R., Kahn, R. S., & De Haan, E. H. (2000). Perception, mental imagery and reality discrimination in hallucinating and non-hallucinating schizophrenic patients. *British Journal of Clinical Psychology*, *39*(4), 397–406. https://doi.org/10.1348/014466500163392

Collerton, D., Barnes, J., Diederich, N. J., Dudley, R., ffytche, D., Friston, K., Goetz, C. G., Goldman, J. G., Jardri, R., Kulisevsky, J., Lewis, S. J. G., Nara, S., O'Callaghan, C., Onofrj, M., Pagonabarraga, J., Parr, T., Shine, J. M., Stebbins, G., Taylor, J. P., Tsuda, I., Weil, R. S. (2023). Understanding visual hallucinations: A new synthesis. *Neuroscience and Biobehavioral Reviews*, *150*, 105208. https://doi.org/10.1016/j.neubiorev.2023.105208

Dang, J., King, K. M., & Inzlicht, M. (2020). Why are self-report and behavioral measures weakly correlated? *Trends in Cognitive Sciences*, *24*(4), 267–269. https://doi.org/10.1016/j.tics.2020.01.007

Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern span: A tool for unwelding visuo-spatial memory. *Neuropsychologia*, *37*(10), 1189–1199. https://doi.org/10.1016/S0028-3932(98)00159-6

de Leede-Smith, S., & Barkus, E. (2013). A comprehensive review of auditory verbal hallucinations: Lifetime prevalence, correlates and mechanisms in healthy and clinical individuals. *Frontiers in Human Neuroscience*, *16*(7), 367. Frontiers Media S. A. https://doi.org/10.3389/fnhum.2013.00367

Dudley, R., Kuyken, W., & Padesky, C. A. (2011). Disorder specific and trans-diagnostic case conceptualisation. *Clinical Psychology Review*, *31*(2), 213–224. https://doi.org/10.1016/j.cpr.2010.07.005

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fazekas, P. (2021). Hallucinations as intensified forms of mind-wandering. *Philosophical Transactions of the Royal Society B*, *376*(1817), 20190700. https://doi.org/10.1098/rstb.2019.0700

Fernyhough, C. (2019). Modality-general and modality-specific processes in hallucinations. *Psychological Medicine*, *49*(16), 2639–2645. https://doi.org/10.1017/S0033291719002496

Flake, J. K., & Fried, E. I. (2020). Measurement schmeasurement: Questionable measurement practices and how to avoid them. *Advances in Methods and Practices in Psychological Science*, *3*(4), 456–465. https://doi.org/10.1177/2515245920952393

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*(3), 1166–1186. https://doi.org/10.3758/s13428-017-0935-1

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review*, *30*(3), 349–362. https://doi.org/10.1016/j.cpr.2010.01.001

Ison, R., Medoro, L., Keen, N., & Kuipers, E. (2014). The use of rescripting imagery for people with psychosis who hear voices. *Behavioural and Cognitive Psychotherapy*, *42*(2), 129–142. https://doi.org/10.1017/S135246581300057X

Ji, J. L., Kavanagh, D. J., Holmes, E. A., MacLeod, C., & Di Simplicio, M. (2019). Mental imagery in psychiatry: Conceptual & clinical implications. *CNS Spectrums*, *24*(1), 114–126. https://doi.org/10.1017/S1092852918001487

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review*, *88*(1), 67. https://doi.org/10.1037/0033-295X.88.1.67

Kosslyn, S. M., Margolis, J. A., Barrett, A. M., Goldknopf, E. J., & Daly, P. F. (1990). Age differences in imagery abilities. *Child Development*, *61*(4), 995–1010. https://doi.org/10.1111/j.1467-8624.1990.tb02837.x

Kosslyn, S. M., Chabris, C. F., Shephard, J. M., & Thompson, W. L. (1998). *Spontaneous use of imagery scale (SUIS)* [Unpublished manuscript].

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience*, *2*(9), 635–642. https://doi.org/10.1038/35090055

Kozhevnikov, M., Kosslyn, S. M., & Shepard, J. (2005). Spatial versus object visualizers: A new characterization of visual cognitive style. *Memory and Cognition*, *33*(4), 710–726. https://doi.org/10.3758/BF03195337

Lee, I. A., & Preacher, K. J. (2013). Calculation for the test of the difference between two dependent correlations with one variable in common [Computer software]. http://quantpsy.org

Lequerica, A., Rapport, L., Axelrod, B. N., Telmet, K., & Whitman, R. D. (2002). Subjective and objective assessment methods of mental imagery control: Construct validations of self-report measures. *Journal of Clinical and Experimental Neuropsychology*, *24*(8), 1103–1116. https://doi.org/10.1076/jcen.24.8.1103.8370

Lim, A., Hoek, H. W., Deen, M. L., Blom, J. D., Bruggeman, R., Cahn, W., de Haan, L., Kahn, R. S., Meijer, C. J., Myin-Germeys, I., van Os, J., Wiersma, D., & GROUP Investigators. (2016). Prevalence and classification of hallucinations in multiple sensory modalities in schizophrenia spectrum disorders. *Schizophrenia Research*, *176*(2-3), 493–499. https://doi.org/10.1016/j.schres.2016.06.010

Linszen, M. M. J., de Boer, J. N., Schutte, M. J. L., Begemann, M. J. H., de Vries, J., Koops, S., Blom, R. E., Bohlken, M. M., Heringa, S. M., Blom, J. D., & Sommer, I. E. C. (2022). Occurrence and phenomenology of hallucinations in the general population: A large online survey. *Schizophrenia*, *8*(1), 41. https://doi.org/10.1038/s41537-022-00229-9

Little, R. J. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*, *83*(404), 1198–1202. https://doi.org/10.1080/01621459.1988.10478722

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology*, *64*(1), 17–24. https://doi.org/10.1111/j.2044-8295.1973.tb01322.x

McCarthy-Jones, S., Smailes, D., Corvin, A., Gill, M., Morris, D. W., Dinan, T. G., Murphy, K. C., O'Neill, F. A., Waddington, J. L., Australian Schizophrenia Research Bank, Donohoe, G., & Dudley, R. (2017). Occurrence and co-occurrence of hallucinations by modality in schizophrenia-spectrum disorders. *Psychiatry Research*, *252*, 154–160. https://doi.org/10.1016/j.psychres.2017.01.102

McGrath, J. J., Saha, S., Al-Hamzawi, A., Alonso, J., Bromet, E. J., Bruffaerts, R., Caldas-de-Almeida, J. M., Chiu, W. T., deJonge, P., Fayyad, J., & Florescu, S. (2015). Psychotic experiences in the general population: A cross-national analysis based on 31 261 respondents from 18 countries. *JAMA Psychiatry*, *72*(7), 697–705. https://doi.org/10.1001/jamapsychiatry.2015.0575

Mitchell, C. A., Maybery, M. T., Russell-Smith, S. N., Collerton, D., Gignac, G. E., & Waters, F. (2017). The structure and measurement of unusual sensory experiences in different modalities: The multi-modality unusual sensory experiences questionnaire (MUSEQ). *Frontiers in Psychology*, *8*(Aug), 1363. https://doi.org/10.3389/fpsyg.2017.01363

Moseley, P., Alderson-Day, B., Common, S., Dodgson, G., Lee, R., Mitrenga, K., Moffatt, J., & Fernyhough, C. (2022). Continuities and discontinuities in the cognitive mechanisms associated with clinical and nonclinical auditory verbal hallucinations. *Clinical Psychological Science*, *10*(4), 752–766. https://doi.org/10.1177/21677026211059802

Moseley, P., Aleman, A., Allen, P., Bell, V., Bless, J., Bortolon, C., Cella, M., Garrison, J., Hugdahl, K., Kozáková, E., Larøi, F., Moffatt, J., Say, N., Smailes, D., Suzuki, M., Toh, W. L., Woodward, T., Zaytseva, Y., Rossell, S., & Fernyhough, C. (2021). Correlates of hallucinatory experiences in the general population: An international multisite replication study. *Psychological Science*, *32*(7), 1024–1037. https://doi.org/10.1177/0956797620985832

Murphy, B. A., & Lilienfeld, S. O. (2019). Are self-report cognitive empathy ratings valid proxies for cognitive empathy ability? Negligible meta-analytic relations with behavioral task performance. *Psychological Assessment*, *31*(8), 1062. https://doi.org/10.1037/pas0000732

Nanay, B. (2016). Hallucination as mental imagery. *Journal of Consciousness Studies*, *23*(7-8), 65–81.

Noordzij, M. L., Zuidhoek, S., & Postma, A. (2007). The influence of visual experience on visual and spatial imagery. *Perception*, *36*(1), 101–112. https://doi.org/10.1068/p5390

Pearson, D. G., Deeprose, C., Wallace-Hadrill, S. M., Heyes, S. B., & Holmes, E. A. (2013). Assessing mental imagery in clinical psychology: A review of imagery measures and a guiding framework. *Clinical Psychology Review*, *33*(1), 1–23. https://doi.org/10.1016/j.cpr.2012.09.001

Policardi, E., Perani, D., Zago, S., Grassi, F., Fazio, F., & Ladavas, E. (1996). Failure to evoke visual images in a case of long-lasting cortical blindness. *Neurocase*, *2*(5), 381–394.

Pylyshyn, Z. W. (2002). Mental imagery: In search of a theory. *Behavioral and Brain Sciences*, *25*(2), 157–182. https://doi.org/10.1017/S0140525X02000043

Reichert, D. P., Series, P., & Storkey, A. J. (2013). Charles Bonnet syndrome: Evidence for a generative model in the cortex? *PLoS Computational Biology*, *9*(7), e1003134. https://doi.org/10.1371/journal.pcbi.1003134

Saunders, B., Milyavskaya, M., Etz, A., Randles, D., & Inzlicht, M. (2018). Reported self-control is not meaningfully associated with inhibition-related executive function: A Bayesian analysis. *Collabra: Psychology*, *4*(1), Article 39. https://doi.org/10.1525/collabra.134

Sheaves, B., Johns, L., Loe, B. S., Bold, E., Černis, E., Molodynski, A., & Freeman, D. (2023). Listening to and believing derogatory and threatening voices. *Schizophrenia Bulletin*, *49*(1), 151–160. https://doi.org/10.1093/schbul/sbac101

Sheaves, B., Onwumere, J., Keen, N., & Kuipers, E. (2015). Treating your worst nightmare: A case-series of imagery rehearsal therapy for nightmares in individuals experiencing psychotic symptoms. *The Cognitive Behaviour Therapist*, *8*, e27. https://doi.org/10.1017/S1754470X15000665

Shine, J. M., O'Callaghan, C., Halliday, G. M., & Lewis, S. J. (2014). Tricks of the mind: Visual hallucinations as disorders of attention. *Progress in Neurobiology*, *116*, 58–65. https://doi.org/10.1016/j.pneurobio.2014.01.004

Slotnick, S. D., Thompson, W. L., & Kosslyn, S. M. (2005). Visual mental imagery induces retinotopically organized activation of early visual areas. *Cerebral Cortex*, *15*(10), 1570–1583. https://doi.org/10.1093/cercor/bhi035

Smailes, D., Alderson-Day, B., Hazell, C., Wright, A., & Moseley, P. (2022). Measurement practices in hallucinations research. *Cognitive Neuropsychiatry*, *27*(2-3), 183–198. https://doi.org/10.1080/13546805.2021.1999224

Spearman, C. (1910). Correlation calculated from faulty data. *British Journal of Psychology*, *3*(3), 271. https://doi.org/10.1111/j.2044-8295.1910.tb00206.x

Steinke, A., & Kopp, B. (2020). RELEX: An excel-based software tool for sampling split-half reliability coefficients. *Methods in Psychology*, *2*, 100023. https://doi.org/10.1016/j.metip.2020.100023

Taylor, C. D. J., Bee, P. E., & Haddock, G. (2019). *iMAgery-focused psychological therapy for persecutory delusions in PSychosis (iMAPS): A novel treatment approach*. www.elsevier.com/locate/cabp

Toh, W. L., Thomas, N., Robertson, M., & Rossell, S. L. (2020). Characteristics of non-clinical hallucinations: A mixed-methods analysis of auditory, visual, tactile and olfactory hallucinations in a primary voice-hearing cohort. *Psychiatry Research*, *289*, 112987. https://doi.org/10.1016/j.psychres.2020.112987

Ursachi, G., Horodnic, I. A., & Zait, A. (2015). How reliable are measurement scales? External factors with indirect influence on reliability estimators. *Procedia Economics and Finance*, *20*, 679–686. https://doi.org/10.1016/S2212-5671(15)00123-9

Waters, F., Woodward, T., Allen, P., Aleman, A., & Sommer, I. (2012). Self-recognition deficits in schizophrenia patients with auditory hallucinations: A meta-analysis of the literature. *Schizophrenia Bulletin*, *38*(4), 741–750. https://doi.org/10.1093/schbul/sbq144