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Research Paper

Cognitive and perceptual impairments in schizophrenia extend to other psychotic disorders but not schizotypy

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ABSTRACT

Well characterised cognitive and perceptual impairments in schizophrenia may not be diagnostically specific with some studies suggesting no significant differences between psychotic disorders. This transdiagnostic ambiguity is paralleled in the boundary distinctions between psychotic disorders and the sub-threshold symptomatology of schizotypy. The current study used the CNTRACS test battery to explore if performance deficits in visual integration, relational memory and goal maintenance were specific to schizophrenia or extend to other psychotic disorders; and if task performance varied between individuals with schizophrenia and schizotypy in healthy adults. The sample consisted of healthy controls, and patients who met DSM-IV criteria for schizophrenia, other psychotic disorders and non-psychotic disorders who were tested in person; and an online sample of self-assessed healthy adults. No significant differences were found in performance between patients with schizophrenia and other psychotic disorders in contrast to non-psychotic disorders and healthy controls. The high schizotypy group performed better on the tasks compared to the other psychoses and schizophrenia groups. There were no differences in the healthy control group between individuals with high versus low schizotypy or between in-person and online task performance. These findings support the notion that cognitive and perceptual impairments in schizophrenia extend to other psychotic disorders but are discontinuous with schizotypy. This study provides insights into similarities between schizophrenia and other psychotic disorders with regards to the potential neural substrates underpinning these functions and supports the use of online tools for assessing domains of cognition and perception.

1. Introduction

Schizophrenia is a disorder characterised by extensive cognitive and perceptual impairments (McCleery and Nuechterlein, 2019; Sheffield et al., 2018) including visual integration, relational encoding and retrieval, and goal maintenance domains. These are relevant to functional outcomes in schizophrenia (Barch et al., 2009; Green, 2009; Ragland et al., 2009; Wells et al., 2015) and have all been demonstrably linked to neural systems (Mukherjee et al., 2016; Poppe et al., 2016; Silverstein et al., 2015; Tripathi et al., 2018) providing opportunity for translational research (Barch et al., 2009).

However, the diagnostic specificity of these findings is not well resolved and the limited literature comparing visual integration, relational memory and goal maintenance performance across different psychiatric illnesses, suggests that individuals with psychotic disorders do not significantly differ in task performance. For example, Owoso et al. (2013) found no major quantitative differences between schizophrenia and schizoaffective patient groups in these three domains with both

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uniformly performing worse than healthy controls. Likewise, Smucny et al. (2020) concluded that impaired visual integration performance was not specific to schizophrenia but also present in bipolar I and schizoaffective disorders. This is consistent with transdiagnostic ambiguity in cognitive and perceptual domains between psychotic disorders (East-Richard et al., 2020).

To assist in the disambiguation of cognition and perception between schizophrenia and other psychotic disorders relatively specific tasks for cognitive and perceptual domains were identified by the Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia project (CNTRICS; Carter and Barch, 2007) and more recently, the CNTRACS (Cognitive Neuroscience Test Reliability and Clinical Applications for Schizophrenia; Gold, 2012) consortium. With regards to visual integration, relational encoding and retrieval, and goal maintenance, the Jittered Orientation Visual Integration (JOVI), Relational and item-Specific Encoding (RiSE) and the Dot Pattern Expectancy (DPX) tasks were respectively designated as useful measures for these domains. The JOVI, RiSE and DPX lack significant inter-correlation (Gold et al., 2012; Smucny et al., 2020) indicating three distinctive domains of cognition and perception. These tasks have proven psychometric characteristics as well as good construct validity (Jones et al., 2010; Ragland et al., 2012; Silverstein et al., 2012) and are well tolerated by patients.

Using the JOVI, RiSE and DPX tasks, previous studies have repeatedly demonstrated significant impairments in schizophrenia spectrum participants compared to healthy controls (Jones et al., 2010; Keane et al., 2014; Poppe et al., 2016; Ragland et al., 2015; Silverstein et al., 2012; Williams et al., 2010; Barch et al., 2003; Cohen et al., 1999). These findings add support to claims that these tasks provide valid and sensitive measures of impaired cognitive and perceptual function specific to schizophrenia (Lopez-Garcia et al., 2016; Ragland et al., 2012; Silverstein et al., 2012).

Therefore, the diagnostic specificity remains unresolved with existing data conflicted about deficits overlapping with other disorders consistent with both dimensional and categorical views of psychosis. However, no study to date has compared performance on these tasks across a mixed psychiatric inpatient population.

This categorical-dimensional psychosis controversy is paralleled in the distinction between psychotic disorders and sub-threshold or non-clinical psychotic symptomatology conceptualised as schizotypy. Substantial evidence suggests that schizotypy and clinical schizophrenia have significant overlap in terms of genetic, biological and psychosocial factors (Ripke et al., 2013). However, whether this is as an "endophenotype" in the general population for schizophrenia or if it is a distributed dimension throughout the entire population is contested (Grant et al., 2018). Moreover, there is limited conflicting data as to whether the impaired cognitive and perceptual domains observed in people with psychotic disorders also extend into schizotypy (Ettinger et al., 2015; Sahakyan et al., 2019). The psychosis continuum theory would predict, similar to psychotic symptoms, cognitive and perceptual function would be diminished in participants with high schizotypy compared to participants with low schizotypy (Xavier et al., 2015).

The current study aimed to expand the current understanding by testing whether cognitive and perceptual dysfunction is specific to schizophrenia compared to other psychotic and non-psychotic disorders using the JOVI, RiSE and DPX, and if there is cognitive and perceptual function discontinuity between schizophrenia and schizotypy in these domains. Additionally, given the increasing use of online assessments, a sub aim was to assess the validity of the JOVI, RiSE and DPX in an online context.

It was hypothesised that: (1) patients with schizophrenia and other psychotic disorders will show significantly worse performance on the three tasks than patients with non-psychotic disorders and healthy controls; and (2a) healthy controls with high schizotypy scores will show similar but milder patterns of cognitive impairment compared to patients with schizophrenia and other psychotic disorders, and (2b) that there will be a negative association between schizotypy and performance on the tasks.

2. Methods

2.1. Participants

The in-person sample was recruited from patients admitted to adult psychiatric inpatient units at two metropolitan hospitals (the Northern Hospital and the Monash Medical Centre) in Melbourne, Australia and opportunistically from staff, students and colleagues. Participants were patients who met DSM-IV (4th ed, Text Revision; DSM-IV-TR; American Psychiatric Association, 2000) criteria for schizophrenia and a range of other psychotic and non-psychotic disorders as assessed by an independent consultant psychiatrist, and healthy controls who did not meet criteria for any disorder.

The online sample initially consisted of 153 participants. Three participants did not meet the age criterion, three used psychotropic medication and 36 had very poor task performance (i.e., accuracy below chance level). The final online sample consisted of 111 self-assessed healthy adults from Australia and the UK.

Participation was voluntary, consent was informed (in-person study), participants could withdraw from the study at any time and participants were reimbursed for their time. Ethical approvals were obtained from the Melbourne Health and Monash University Human Research Ethics Committees.

2.2. Materials

2.2.1. Positive and Negative Syndrome Scale (PANSS)

The PANSS measures positive symptoms, negative symptoms and general psychopathology through an assessment of behavioural manifestations via interview and reports from family members and hospital staff (Kay et al., 1987). It comprises 30 items and each item is scored from one to seven, ascending in severity.

2.2.2. Community Assessment of Psychic Experiences (CAPE)

The CAPE is a 42 item self-report psychological inventory which measures the level of schizotypy in an individual (Stefanis et al., 2002). The measure is not used to diagnose people but to assess the severity of schizotypy characteristics in the general population.

2.2.3. Jittered Orientation Visual Integration

The JOVI task is composed of a background of Gabor elements, which correspond to the primary visual cortex receptive field organization, placed at various orientations (Silverstein et al., 2012). Participants are required to identify fragmented egg shapes amongst this array and judge whether the shapes point towards the left or right by tapping the left and right arrow keys on their keyboard (Silverstein et al., 2012).

2.2.4. Computerised item Specific and Relational Memory Cognitive Task

The RiSE is a psychometrically valid and reliable measure of relational and item-specific memory for healthy adults and individuals with schizophrenia (Ragland et al., 2012). It involves four subtasks which measure item specific encoding, relational encoding, item specific retrieval and relational retrieval.

2.2.5. The Dot Pattern Expectancy Task

The DPX task was used to measure goal maintenance. Participants were required to respond after a cue and probe stimuli and received auditory feedback after each stimulus. The DPX has shown to be a reliable measure of goal maintenance with a high internal consistency (Jones et al., 2010). To minimise response bias, response patterns were used to compute d'Context scores of overall sensitivity. Correct hits on the target "AX" trials were calculated as: (Correct hits + 0.05) / (Total target trials + 1); and the false alarms on the rule-based "BX" trials as (False alarms + 0.05) / (Total rule-based trials + 1). d'Context scores

Table 1
Demographic data for both online and in-person participant groups.

	DPX					RiSE					JOVI				
	Online HC	In-person HC	SZ	PS	Non-PS	Online HC	In-person HC	SZ	PS	Non-PS	Online HC	In-person HC	SZ	PS	Non-PS
N	105	20	16	12	8	111	20	17	9	9	102	20	13	11	8
Sex															
Female	40	10	6	4	4	41	10	7	5	6	39	10	4	8	4
Male	64	10	10	8	4	69	10	10	4	3	63	10	9	3	4
M_{age} (SD)	30.60 (8.81)	28.00 (12.1)	37.10 (8.1)	33.80 (8.5)	31.00 (7.5)	30.20 (8.78)	25.70 (8.34)	38.35 (5.93)	38.33 (10.05)	45.33 (12.69)	31.01 (8.93)	28.00 (12.09)	38.60 (9.30)	34.50 (8.49)	31.00 (7.54)
Location															
UK	49					51					47				
Australia	56					60					55				

DPX = Dot Expectancy Task, RiSE = Computerised item Specific and Relational Memory Cognitive Task, JOVI = Jittered Orientation Visual Integration, HC = healthy control, SZ = schizophrenia, PS = other psychoses, Non-PS = non-psychosis.

were then computed using a formula recommended by Macmillan and Creelman (1996): d'Context = z(Hit rate) − z(False alarms).

2.3. Procedure

2.3.1. In-person study

All in-person participants first completed a demographics questionnaire that screened for eligibility, and assessed age, gender, education level, diagnosis, illness duration, substance use and psychiatric history. Participants then commenced the tasks: JOVI, RiSE and DPX, where instructions were read aloud to every participant and participants completed practice trials for that task. Practice trials were administered as per the CNTRACS protocols (Silverstein et al., 2012; Ragland et al., 2012; Jones et al., 2010) and when criteria were met participants proceeded to the task questions. Note that in-person participation varied between tasks (specific participant numbers and demographic details for each task are in Table 6). The in-person participants also completed the NART (National Adult Reading Test; Nelson and Wilson, 1991) and patients were administered the PANSS. Participants were permitted to take a short break between task blocks if required. The overall duration of the in-person study was approximately 4 h.

2.3.2. Online schizotypy study

The study was advertised online via the Amazon MTurk recruitment website. Participants were asked to read the eligibility criteria and the study information sheet before providing their consent. Participant task submissions were de-identified through MTurk's process of assigning anonymous Worker Number IDs. Participants first completed a demographics form providing their computer screen dimensions and resolution, age, country of birth, education level, employment status, gender, medical conditions and medications and primary language. Participants were then redirected to Pavlovia.org, where they commenced the three cognitive tasks. The order of the JOVI, RiSE and DPX tasks varied between participants to account for differences in performance due to task order. Practice trials were embedded at the beginning of each of the tasks. After this, participants completed the CAPE. The duration of the study was approximately 1 h, however participants had 3 h available to complete the tasks.

Table 3
Descriptive statistics (mean (standard deviation)) for Community Assessment of Psychic Experiences (CAPE) total and subscale scores for all participants in the online schizotypy study.

	CAPE total	CAPE positive	CAPE negative	CAPE depressive
JOVI dataset	70.96 (15.50)	1.46 (0.34)	1.89 (0.53)	1.90 (0.52)
RiSE dataset	70.60 (15.22)	1.46 (0.34)	1.88 (0.52)	1.88 (0.51)
DPX dataset	71.09 (15.40)	1.47 (0.34)	1.90 (0.52)	1.90 (0.52)

JOVI = Jittered Orientation Visual Integration, RiSE = Computerised item Specific and Relational Memory Cognitive Task, DPX = Dot Expectancy Task.

2.4. Statistical analyses

Spearman's correlational analyses were performed to assess any confounding effects of age, on d'Context, RiSE, JOVI, CAPE-42, and PANSS scores. Age was identified as a confounding variable in JOVI and RiSE in-person and online samples. No moderating variables were found in the DPX in-person sample, but age and education level were identified in the DPX online sample.

To assess the size and direction of the linear association between performance on the cognitive and perceptual tasks and scores on the PANSS and its component subscales for the patient group, a Spearman's rank correlation coefficient (r_s) was calculated with a Bonferroni adjusted α level of 0.016 (0.05/3) per test. To assess the size and direction of the linear association between performance on the cognitive tasks and scores on the CAPE and its component subscales for the online healthy control group, a Spearman's rank correlation coefficient (r_s) was calculated with a Bonferroni adjusted α level of 0.016 (0.05/3) per test. Unless otherwise stated, an alpha level (α) of 0.05 was used in the analyses.

Table 2
Descriptive statistics (mean (standard deviation)) for Positive and Negative Syndrome Scale (PANSS) total and subscale scores for all participants in the in-person psychiatric inpatient study.

	PANSS total	PANSS positive	PANSS negative	PANSS disorganised	PANSS general psychopathology
JOVI dataset	73.31 (13.92)	18.09 (5.89)	16.88 (6.83)	20.56 (7.55)	38.34 (7.06)
RiSE dataset	52.43 (9.44)	15.11 (6.30)	10.77 (3.62)	15.63 (4.89)	26.54 (4.87)
DPX dataset	74.17 (14.55)	18.53 (5.97)	16.92 (6.91)	21.33 (7.70)	38.72 (7.47)

JOVI = Jittered Orientation Visual Integration, RiSE = Computerised item Specific and Relational Memory Cognitive Task, DPX = Dot Expectancy Task.

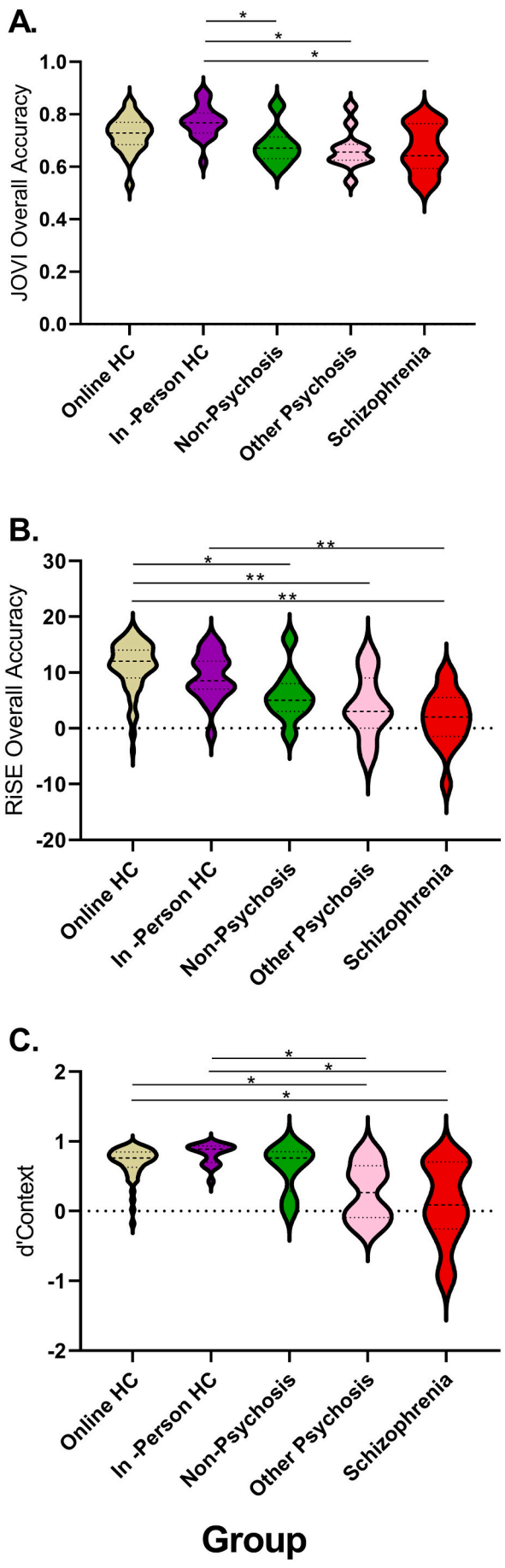

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Fig. 1. Group comparisons of performance on the A. Jittered Orientation Visual Integration (JOVI); B. Computerised item Specific and Relational Memory Cognitive Task (RiSE); and C. Dot Expectancy Task expressed as d'Context (see Methods). Lines over plots represent groups which were significantly different. *p < .05; **p < .01; HC = healthy control.

3. Results

3.1. Demographic and clinical data

Demographic information including sample size, sex, age and location for all participant groups and in each of the tasks is shown in Table 1.

3.2. Symptom and schizotypy ratings

The descriptive statistics for the PANSS scores associated with the psychiatric inpatient sample are provided in Table 2. As the online samples were not fully overlapping, descriptive statistics for the CAPE measures relating to the participants included in the JOVI, RiSE and DPX task analyses are provided in Table 3.

3.3. Between group differences in task performance

3.3.1. JOVI

An ANCOVA, covarying for age, between the online healthy control, in-person healthy control, non-psychosis, other psychoses, and schizophrenia patient groups revealed statistically significant differences in JOVI scores ($F(4, 98) = 4.762$, $p = .001$, $\eta^2_g = 0.163$). As shown in Fig. 1A, controlling for age, Tukey post hoc analyses revealed the in-person healthy controls ($M = 0.77$, $SD = 0.06$) performed significantly better on the JOVI than the non-psychosis ($M = 0.68$, $SD = 0.07$), the other psychoses ($M = 0.67$, $SD = 0.08$) and the schizophrenia groups ($M = 0.67$, $SD = 0.09$). There were no significant differences between the online healthy controls ($M = 0.73$, $SD = 0.07$) and the in-person healthy controls.

3.3.2. RiSE

An ANCOVA, covarying for age, revealed a significant main effect between groups ($F(4,160) = 17.93$, $p < .001$, $\eta^2_g = 0.310$) on RiSE task performance (Fig. 1B). Tukey post hoc analyses revealed RiSE scores were significantly higher for online ($M = 11.20$, $SD = 4.32$) and in-person ($M = 9.25$, $SD = 4.20$) healthy control groups compared to the schizophrenia group ($M = 1.82$, $SD = 4.92$). There were also significant differences between the online healthy control group and the other psychoses ($M = 3.89$, $SD = 5.73$) and the non-psychosis ($M = 5.89$, $SD = 4.73$) groups. No other significant differences were found.

3.3.3. DPX

A Kruskal-Wallis test demonstrated statistically significant differences in performance on the DPX task between groups (Chi square = 37.07, $p < .001$, $df = 5$, $\eta^2_H = 0.305$) (Fig. 1C). Multiple comparison post-hoc analyses with Dunn's test revealed that schizophrenia patients had significantly lower d'Context scores ($M = 0.11$, $SD = 0.57$) than online ($M = 0.70$, $SD = 0.23$) and in-person ($M = 0.82$, $SD = 0.15$) healthy controls. There were no significant differences in performance on the task between patients with schizophrenia, non-psychosis ($M = 0.92$, $SD = 0.05$) and other psychoses groups ($M = 0.72$, $SD = 0.22$).

3.4. Association between symptom profiles and schizotypy scores and task performance

3.4.1. In-person study

For both, RiSE overall accuracy and DPX ranked d'Context scores, there were significant negative correlations with PANSS total scores, and

Table 4
Spearman's correlations between overall task accuracy for the Jittered Orientation Visual Integration (JOVI) (n = 32), Computerised item Specific and Relational Memory Cognitive Task (RiSE) (n = 35) and Dot Expectancy Task (n = 36) and Positive and Negative Syndrome Scale (PANSS) total and sub-scale scores for all participants in the in-person psychiatric inpatient study.

Task	PANSS total	PANSS positive	PANSS negative	PANSS disorganised	PANSS general
JOVI	0.048 (0.799)	−0.176 (0.336)	0.089 (0.630)	−0.226 (0.214)	0.108 (0.556)
RiSE	−0.419 (0.012)*	−0.473 (0.004)*	−0.230 (0.184)	−0.456 (0.006)*	−0.030 (0.866)
DPX	−0.41 (0.012)*	−0.63 (<0.001)*	−0.05 (0.780)	−0.60 (<0.001)*	−0.15 (0.387)

* $p < .016$.

Table 5
Spearman's correlations between overall task accuracy for the Jittered Orientation Visual Integration (JOVI), Computerised item Specific and Relational Memory Cognitive Task (RiSE) and Dot Expectancy Task and Community Assessment of Psychic Experiences (CAPE) total and subscale scores for all participants in the online schizotypy study.

	CAPE total	CAPE positive	CAPE negative	CAPE depressive
JOVI dataset	0.067 (0.506)	0.038 (0.711)	0.056 (0.575)	0.053 (0.598)
RiSE dataset	−0.146 (0.131)	−0.192 (0.045)	−0.100 (0.301)	−0.063 (0.514)
DPX dataset	−0.12 (0.223)	−0.01 (0.912)	−0.12 (0.218)	−0.20 (0.039)

Values in parentheses are p-values.

the positive and disorganised subscales (Table 4).

3.4.1.1. Psychotropic medication. Antipsychotic drug doses (expressed as chlorpromazine equivalents) and benzodiazepine drug doses (expressed as diazepam equivalents) (Table 6) showed no significant differences between patient groups for those completing the RiSE and DPX tasks. For those completing the JOVI task, Kruskal-Wallis analysis demonstrated statistically significant differences in antipsychotic doses between clinical groups ($F(2,32) = 8.07$, $p < .018$) with a pairwise Wilcoxon analysis showing significantly higher doses in the Other Psychoses ($M_D = 254.56$, $p = .042$) and the Schizophrenia ($M_D = 321.07$, $p = .036$) groups compared to the Non-Psychosis group. However, there were no differences in benzodiazepine doses for this group. Antipsychotic drug dose did not significantly correlate with task performance on the JOVI ($r = -0.099$, $p = .589$), RiSE ($r = 0.217$, $p = .345$) or DPX ($r = -0.941$, $p = .354$); nor did benzodiazepine drug dose and task performance on the JOVI ($r = -0.24$, $p = .184$), RiSE ($r = 0.087$, $p = .777$) or DPX ($r = 0.695$, $p = .492$).

3.4.2. Online study

As shown in Table 5, there were no statistically significant associations between performance on the cognitive tasks and scores on the CAPE and its component subscales.

3.4.2.1. Online schizotypy sample versus in-person healthy controls cognitive function. As shown in Fig. 2, there were no significant differences in task performance between the online low and high schizotypy groups and in-person healthy controls. Low and high schizotypy groups were formed by splitting the online group into quartiles based on total CAPE score and selecting the lowest and highest quartiles.

4. Discussion

Visual integration, relational memory and goal maintenance are processes that are commonly impaired in individuals with schizophrenia, though substantially less is known about how these cognitive impairments relate to other psychotic disorders and schizotypy.

This study first explored if impairments in these tasks were specific to schizophrenia or if they generalised to other psychotic and non-psychotic disorders. While clear differences were seen between individuals with a diagnosis of schizophrenia and healthy controls, no differences were found between patients with schizophrenia or other psychoses. These findings contrast with claims regarding the diagnostic specificity of impaired performance on the JOVI, RiSE and DPX tasks but are consistent with other work similarly demonstrating that cognitive and perceptual impairments observed in schizophrenia extend to other psychotic disorders (Barch et al., 2003; Owoso et al., 2013; Smucny et al., 2020). These findings align with a dimensional perspective of cognitive and perceptual dysfunction in psychotic disorders differentiating them from non-psychotic disorders and potential confounds such as medication. Moreover, the diagnostic heterogeneity within the other psychoses group and the correlational relationships with psychotic symptoms is suggestive of some possible common mechanisms underlying both these symptoms and cognitive and perceptual domains independent of diagnosis.

The current study further aimed to investigate whether there is continuity in function between schizotypy in healthy controls and

Table 6
Diagnostic and treatment data for the in-person psychiatric participant groups.

	RiSE patient group	DPX patient group	JOVI patient group
Schizophrenia group			
First episode psychosis	0	0	1
Schizoaffective disorder	10	8	6
Schizophrenia	7	8	6
Other Psychoses group			
Post-partum psychosis	0	1	1
Bipolar affective disorder	1	9	8
Depression with psychotic features	0	1	1
Complex PTSD	1	1	1
Non-Psychosis group			
Depression	4	5	5
Depression with comorbid anxiety	1	1	1
Substance abuse	1	2	2
Borderline personality disorder	1	0	0
Medication			
Antipsychotics	29	30	28
Benzodiazepines	17	10	8
Chlorpromazine equivalent (mg)	RiSE patient group	DPX patient group	JOVI patient group
	Mean (SD[a])	Mean (SD)	Mean (SD)
Antipsychotics daily dose			
Schizophrenia group	621.82 (529.16)	487.86 (390.88)	437.78 (383.59)
Other Psychoses group	298.00 (118.83)	369.00 (224.04)	371.27 (234.77)
Non-Psychosis group	154.00 (169.72)	233.25 (151.71)	116.71 (159.44)
Benzodiazepine daily dose (mg)			
Schizophrenia group	23.00 (32.52)	12.50 (5.00)	10.00 (0.00)
Other Psychoses group	17.50 (13.92)	8.33 (2.89)	10.00 (0.00)
Non-Psychosis group	21.00 (19.17)	13.33 (5.77)	13.33 (5.77)

Numbers reported are *n* unless otherwise stated.
JOVI = Jittered Orientation Visual Integration, RiSE = Computerised item Specific and Relational Memory Cognitive Task, DPX = Dot Expectancy Task; PTSD = post-traumatic stress disorder.
[a] SD = standard deviation.

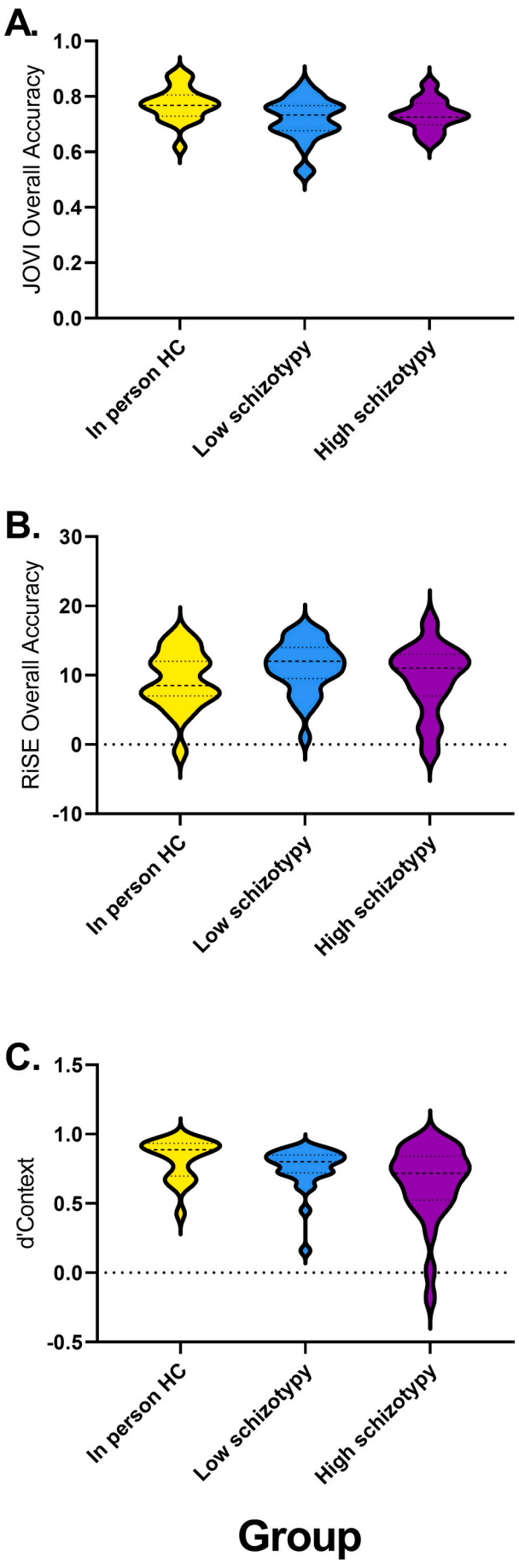

Fig. 2. Group comparisons between the online low and high schizotypy and in-person healthy control (HC; $n = 20$) groups of performance on the A. Jittered Orientation Visual Integration (JOVI; $n_{low} = 27$, $n_{high} = 25$); B. Computerised item Specific and Relational Memory Cognitive Task (RiSE; $n_{low} = 29$, $n_{high} = 28$); and C. Dot Expectancy Task expressed as d'Context (see Methods; $n_{low} = 27$, $n_{high} = 28$).

patients diagnosed with schizophrenia, across the domains of goal maintenance, relational memory, and contour integration. The hypothesis that healthy controls with high schizotypy scores will show similar but milder patterns of cognitive impairment compared to patients with schizophrenia was not supported. Results for the RiSE and DPX tasks showed no significant difference between the high and low schizotypy groups and both were superior to the schizophrenia group. In the case of the JOVI measure of contour integration, the difference between the performance of the online healthy control group was not significantly different from the schizophrenia group however there was again no significant difference between high and low schizotypy group. These findings demonstrate some discontinuity in cognitive and perceptual performance between schizophrenia and people with high schizotypy. This could be consistent with the transition to schizophrenia requiring additional factors to those for psychosis-like symptoms including different neural substrates for sub-threshold symptoms and cognitive and perceptual functioning. These data could also be consistent with a sharp demarcation between schizophrenia and schizotypy in the general population. Until now there have been no studies comparing the performance of healthy controls with high schizotypy against schizophrenia patients on the JOVI, RiSE and DPX. Therefore, this study is the first to demonstrate that cognitive and perceptual performance in these three domains is not dimensional along a sub-threshold non-clinical to clinical psychosis continuum.

Moreover, we found no statistically significant correlation between task performance and schizotypy scores and no difference in task performance when the healthy control group was dichotomised into high versus low schizotypy. This argues against cognitive and perceptual impairments in psychosis sharing a transitional profile into a non-clinical psychosis-like dimension. The current findings are consistent with a recent study (Sahakyan et al., 2019), which found no correlation between relational memory and overall schizotypy levels. However, it contrasts with earlier work showing a gradation of increasing cognitive task impairments from low to high schizotypy that was accompanied by brain activity changes consistent with those seen in individuals with schizophrenia (Ettinger et al., 2015; Xavier et al., 2015).

The study also sought to determine whether the online and in-person versions of the JOVI, RiSE and DPX tasks produced similar performance levels across two different non-clinical samples. Our results showed no statistically significant differences between the online and the in-person healthy control group task scores. This demonstrates for the first time the validity of using the JOVI, RiSE and DPX tasks in an online setting, at least in the general population.

While the online format did not allow for a fully controlled study environment, which may have influenced the outcome, it had other advantages over in-person assessment. Implementing computerized cognitive tasks and collecting data in a novel online format allowed efficient sample recruitment. Additionally, despite the participants in patient groups receiving different medication types and doses, there were no statistically significant differences in task performance and there were no significant correlations between task performance and drug dose. Thus, it is unlikely that medication significantly influenced the results of the current study. As is reflected in the PANSS scores presented in Table 4, illness severity in the in-patient participant groups is mild-moderate which was considered sufficiently stable to manage participation in the tasks, and unlikely to have influenced task performance. Finally, it is possible that the lack of significant group differences between psychiatric groups on the CNTRACS measures may be due to

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low statistical power as a result of small sample sizes for the in-person patient groups.

The current study's findings support the notion that cognitive and perceptual impairments in schizophrenia extend to other psychotic disorders but are discontinuous with schizotypy. Our findings suggest that cognitive deficits that are present in schizophrenia are not present in individuals with high schizotypy and it therefore does not support schizotypy as a useful construct to study cognitive and perceptual deficits in schizophrenia. This study provides insights into similarities between schizophrenia and other psychotic disorders with regards to the potential neural substrates underpinning these cognitive and perceptual functions.

Ethical approval

Ethical approval for the study was given by the Melbourne Health (for the Northern Hospital site and in-person healthy control arms) and Monash University (for the Monash Medical Centre site and online arms) Human Research Ethics Committees and all participants gave informed consent.

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CRediT authorship contribution statement

NF, MG and DR: investigation, formal analysis, writing – original draft
HD: methodology, software, formal analysis, project administration, supervision, resources, writing – review and editing
CR, TM and MM: investigation, formal analysis
RH: supervision, resources, writing – review and editing
OC: conceptualisation, methodology, supervision, resources, funding acquisition, writing – review and editing
SS: conceptualisation, supervision, resources, funding acquisition, writing – review and editing.

Declaration of competing interest

Authors report no potential conflicts of interest relevant to the current paper.

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