

Functional Correlates of Atypical Visuo-perceptual Organization in a Multisite Clinical High-Risk Sample

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Individuals at clinical high risk (CHR) for developing psychotic disorders are thought to exhibit atypical visuo-perceptual organization. Furthermore, CHR status is associated with reduced cognitive, social, and role functioning. We hypothesize that atypical visuo-perceptual organization may lead to downstream

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impairments in cognitive, social, and role functioning. However, the degree to which visuo-perceptual organization can explain such functioning is unclear. Our sample consisted of four groups: a CHR group ($n = 339$), a mild psychotic-like experiences group ($n = 162$), a nonpsychotic clinical group ($n = 111$), and a healthy control group ($n = 199$). We measured perceptual organization via Ebbinghaus and Mooney Faces tasks. In the Ebbinghaus task, participants judged the size of target circles in the presence of surrounding circles. In the Mooney Faces task, participants reported whether they detected faces in two-tone images. Ebbinghaus context sensitivity correlated with measures of cognitive ability such as symbol coding, $r(572) = .13$, $p_{\text{fdr}} = .007$, 95% confidence interval (CI) [0.05, 0.21], verbal learning, $r(608) = .1$, $p_{\text{fdr}} = .016$, 95% CI [0.02, 0.18], and reading ability, $r(550) = .09$, $p_{\text{fdr}} = .038$, 95% CI [0.01, 0.17]. In contrast, Mooney inverted face detection correlated with social functioning, $r(636) = -.09$, $p_{\text{fdr}} = .025$, 95% CI [-0.17, -0.01], role functioning, $r(638) = -.16$, $p_{\text{fdr}} < .001$, 95% CI [-0.23, -0.08], and social phobia severity, $r(616) = .14$, $p_{\text{fdr}} = .001$, 95% CI [0.06, 0.22]. Increased inverted face detection in CHR may reflect overweighting of perceptual priors, which has downstream effects on functioning in school and workplace settings. Contrary to our expectations, Ebbinghaus context sensitivity did not differ between groups but did relate to general cognitive functioning.

General Scientific Summary

The present work assesses the relationship between altered visual perception and real-world functioning in individuals that are at elevated risk of developing psychotic disorders such as schizophrenia. We show that two assessments of visual perception, an ambiguous face detection task and a visual size illusion task, are associated with different real-world outcomes. Individuals who saw more faces tended to struggle more in school and workplace settings, while individuals who were less susceptible to a size illusion tended to have poorer cognitive functioning.

Keywords: vision, social, role, Mooney, Ebbinghaus

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Atypical perceptual experiences are a core symptom of psychosis risk (i.e., clinical high-risk [CHR]) syndromes. Commonly reported atypical perceptual experiences range from overt sensory hallucinations to less severe, but more frequent, perceptual distortions (Miller et al., 1999). In addition to self-reported atypical perceptual experiences, psychosis risk is associated with altered visuo-perceptual organization as measured by behavioral and neuroimaging experiments. In particular, susceptibility to the Ebbinghaus illusion is thought to be reduced in individuals with schizophrenia (Tibber et al., 2013; Uhlhaas, Phillips, Mitchell, & Silverstein, 2006; Uhlhaas, Phillips, Schenkel, & Silverstein, 2006) and CHR (Mittal et al., 2015), though also see Grzeczowski et al. (2018) and V. J. Pokorny et al. (2024). In the Ebbinghaus illusion, the perceived size of a central circle is modulated by the size of flanking circles: larger flanking circles lead to smaller perceived size of the central circle (see Figure 1). Thus, individuals with elevated psychotic traits are thought to be less biased by the size of flanking circles. Importantly, susceptibility to the Ebbinghaus illusion has also been shown to covary with illness state (i.e., relapse vs. recovery) such that measures of perceptual organization may be useful for predicting and measuring clinical outcomes (Silverstein et al., 2013).

Individuals with psychotic disorders and those at CHR are also thought to process faces differently than controls (Darke et al., 2013; Kohler et al., 2010; Williams, Cohen, et al., 2023). In particular, perception of Mooney Faces (Mooney, 1957) is reported to be altered in these populations (Silverstein et al., 2021; Uhlhaas, Linden, et al., 2006). The Mooney Faces are a set of pictures of human faces that have been filtered such that only two luminance intensities (e.g., black and white) are present in each image (see Figure 1). This filtering tends to make the faces more difficult to discern. Interestingly, individuals with schizophrenia were found to detect fewer faces than controls (Uhlhaas, Linden, et al., 2006), while a recent report observed greater face detection rates in individuals at CHR

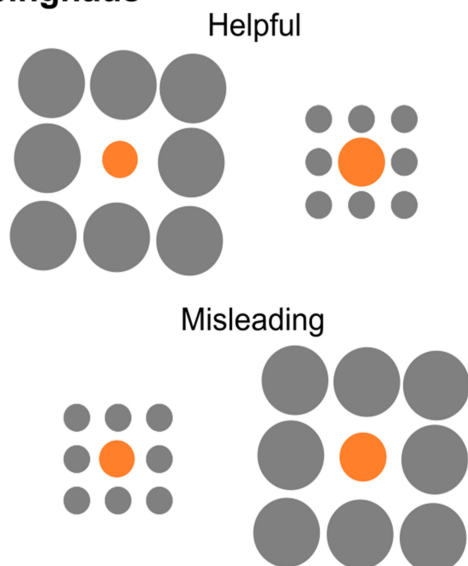
(Silverstein et al., 2021). This apparent discrepancy in the direction of effects has been hypothesized to reflect a moderating effect of illness stage and/or severity on visuo-perceptual organization.

Both the Ebbinghaus and Mooney Faces tasks are thought to measure altered perceptual organization in individuals with psychotic disorders and those at CHR (Silverstein & Keane, 2011). Altered perceptual organization generally has been linked with cognitive disorganization symptoms in schizophrenia populations (Uhlhaas & Silverstein, 2005; Uhlhaas, Phillips, Mitchell, & Silverstein, 2006). Thus, it is possible these two tasks reflect a similar underlying mechanism in psychotic psychopathology. However, these tasks also tap quite different neural and psychological processes. For example, reduced Ebbinghaus context sensitivity is thought to be mediated by altered size representations in the primary visual cortex (Urale & Schwarzkopf, 2023) and/or altered use of visuospatial context (V. J. Pokorny et al., 2024; Urale & Schwarzkopf, 2023). Increased face detection in CHR, on the other hand, is hypothesized to reflect perceptual closure, neurally instantiated as greater activation of the fusiform face area (FFA; McKeef & Tong, 2007). Thus, one of the aims of the present study was to assess the degree to which these two tasks reflect similar or distinct mechanisms of altered visuo-perceptual organization in CHR.

CHR status is associated with impaired cognitive, social, and role functioning (Fusar-Poli et al., 2013; Gur et al., 2014). Indeed, even nonconverters have been shown to have poorer long-term psychosocial outcomes (Beck et al., 2019). We hypothesize that atypical perceptual organization may, in part, cause such functional impairments. As such, we predicted that Ebbinghaus and Mooney Faces task performance would correlate with measures of cognition and psychosocial functioning. Taken together, we aimed to demonstrate the clinical utility and validity of perceptual organization tasks for characterizing and understanding functioning across a spectrum of clinical risk for psychosis.

Figure 1
Ebbinghaus and Mooney Task Stimuli

A. Ebbinghaus



B. Mooney

Upright



Inverted



Note. (A) In the “Helpful” condition example, the left target circle is smaller than the right target circle and the contextual circles accentuate this size difference. In the “Misleading” example, the left circle is still smaller than the right circle, but contextual circles make the sizes seem more similar. (B) Two examples of Mooney Face images, the left image is upright and the right image is inverted. Mooney face images are from “Age in the Development of Closure Ability in Children,” by C. M. Mooney, 1957, *Canadian Journal of Psychology*, 11(4), p. 220 (<https://doi.org/10.1037/h0083717>). Copyright 1957 by the Canadian Psychological Association. See the online article for the color version of this figure.

Method

Participants

Participants were recruited across seven sites in the United States (Northwestern University, University of Maryland-Baltimore County, Yale University, University of Georgia, Temple University, Emory University, and the University of California Irvine) as part of a multisite consortium study of psychosis risk. Recruitment materials included printed and electronic fliers, radio and public transportation advertisements, and mail-outs to community health care providers. Participants were also referred from other ongoing CHR studies.

Participants were deemed to be at CHR based on the Structured Interview for Psychosis-Risk Syndromes criteria (Miller et al., 1999). Participants who did not meet criteria for a psychosis risk syndrome were categorized into three groups: a psychotic-like experiences group (PLE), a nonpsychotic clinical group (CLN), and a healthy control group (HC). The PLE group consisted of individuals who reported some positive symptoms on the Structured Interview for Psychosis-Risk Syndromes but did not meet criteria for a psychosis risk syndrome. We note that it is possible that this distinction between the PLE and CHR groups could be better conceived as a single spectrum of positive symptom severity. Indeed, we are sympathetic to arguments that psychopathology in general is best studied continuously rather than categorically (Kotov et al., 2017). However, in practice, categorical distinctions can be useful. In the case of the study of clinical risk for psychosis, it is commonly theorized that a categorical distinction between those at risk and those with milder positive symptoms is useful for predicting future course of illness. In the present article, we are largely agnostic to which of these conceptualizations contains the greatest degree of verisimilitude and present both dimensional and categorical analyses. Finally, the CLN group consisted of individuals who did not report any positive symptoms but had a current or recent mental health disorder diagnosis.

Exclusion criteria for all participants were severe head trauma, neurological disorder, and psychotic disorder. The study was approved by the institutional review boards of the institutions of all participating sites. All adult participants provided informed consent. Minors provided written assent and their parents or guardians provided written consent.

Procedural Details

All aspects of the study were completed online. On separate days, participants completed clinical interviews, self-report measures, and computerized assessments, in that order. The study included 12-month and 24-month follow-up visits; however, the present article only reports on baseline variables. Follow-up data collection is ongoing at the time of writing. The Ebbinghaus and Mooney Faces tasks were administered within the context of a larger battery of computerized assessments (Mittal et al., 2021). Participant performance was monitored at all times by an assessor to ensure task engagement and minimal environmental disturbances (e.g., ensuring participant was alone in a quiet room with phone turned off). Tasks were coded such that participants could not proceed if the current monitor resolution was not 1,920 × 1,080. Participants were instructed to set their monitors at maximum brightness. When using a laptop, participants were instructed to place their computer on a flat surface and sit in a comfortable chair. Viewing distance was not formally controlled or measured; however, assessors ensured the computer monitor was placed roughly an arm’s length away from the participant.

Brief Assessment of Cognition in Schizophrenia Symbol Coding (BACS-SC)

For the BACS-SC, participants had 90 s to convert symbols to numerals using a decoding key. Performance was measured as the number of correctly written numerals. We chose this measure of cognition because it is well studied in both schizophrenia and CHR populations and has been previously found to exhibit strong convergence with other measures of cognitive functioning (Gerritsen et al., 2020; Keefe et al., 2004; Pratt et al., 2023).

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Hopkins Verbal Learning Test-Revised (HVLТ)

For the HVLТ (Benedict et al., 1998), participants heard a list of 12 words from three semantic categories (four words per category). Then participants were asked to recall as many words as possible. This process was repeated 3 times. The total score was the number of words correctly listed summed across the three trials. We chose this measure of cognition because it is well studied in CHR and schizophrenia populations, and it measures features of cognitive functioning that are not captured by the BACS-SC such as working memory and verbal ability. Also, both BACS-SC and HVLТ are required for tabulating the North American Prodrome Longitudinal Study risk calculator score, which is a focus of the broader parent grant.

Wide Ranging Achievement Test (WRAT)

The third edition of the WRAT was used to measure reading, spelling, and math ability (Wilkinson, 1993). Participants in the present study only completed the letter and word reading portions of the WRAT. In this test, participants were asked to pronounce letters and words that were displayed visually. The total raw score was computed by adding together the number of correctly pronounced words. Raw scores were then normed according to age to create standard scores. This is a useful measure of cognition for our sample because the age-normed scores should sufficiently account for developmental differences.

Global Functioning Role and Social

Global social and role functioning were assessed by presenting participants with a series of verbal prompts relating to their social and role functioning (Cornblatt et al., 2007). After participants responded to these prompts, the interviewer rated social and role functioning on scales of 1–10, with 1 representing *extreme dysfunction* and 10 representing *superior functioning*.

Social Phobia Scale

The Social Phobia Scale (Mattick & Clarke, 1998) consists of 20 items that query feelings of anxiety when performing common actions (i.e., speaking, drinking, and writing) in the presence of other people. Each item is rated on a 5-point Likert scale with 0 corresponding to *not at all characteristic or true of me* and 4 corresponding to *extremely characteristic or true of me*.

Ebbinghaus Task

Stimulus examples from the Ebbinghaus task are presented in Figure 1. There were three conditions: a helpful context condition, a misleading context condition, and a no context condition. In the helpful condition, the contextual circles enhanced the actual size difference between the central target circles. In the misleading condition, the contextual circles obscured this size difference. In the no-context condition, only the central circles were presented. The percent size difference between the two central circles in a given trial could be 2%, 6%, 10%, 14%, or 18%. The laterality of the larger circle and the size difference between central circles were pseudorandomly varied across the task. For each trial, the stimuli were presented for a maximum of 2 s. If the participant did not respond

within this time window, the next trial would begin automatically. Otherwise, the next trial was initiated by the participant's response. This incentivized participants to make quick judgments and also allowed for shorter task durations.

The "misleading index" was calculated by subtracting the mean accuracy for the no-context trials from the mean accuracy for misleading trials. Similarly, the "helpful index" was calculated by subtracting no-context accuracy from helpful trial accuracy. A "context sensitivity index" was calculated by subtracting the misleading index from the helpful index. Finally, we defined "catch trials" as no-context trials with the largest size difference between the two central circles (18%). Five subjects were excluded due to worse-than-chance performance on these catch trials.

Mooney Faces Task

In the Mooney Faces task, participants indicated, via keyboard press, whether they saw a face in a given two-tone image or not. We used 43 of the 44 face images from Lansdell's version of the task (Lansdell, 1968). Thus, faces of men, women, and children of various ages were included. Each image was presented both upright and inverted (i.e., upside-down; see Figure 1) in a pseudorandom order. There was also a scrambled condition intermixed among the upright and inverted trials, but we did not analyze these trials in the present work. Four subjects were excluded because their data contained more trials than the maximum number of possible trials (likely due to data corruption). Each Mooney image was presented for a maximum of 5 s. Similar to the Ebbinghaus task, a participant response within this time window would trigger the next trial. If the subject did not respond within the 5 s time window, the next trial began automatically. For every stimulus, if the subject indicated seeing a face, they were then asked about the gender and age of the face. This was used to check the accuracy of face perception and assess for response bias (see the online supplemental materials for more information).

Analysis

All analyses were conducted in R (R Core Team, 2023). To assess the degree to which task performance related to cognition, social, and role functioning, we computed bivariate Pearson correlations. We adjusted bivariate correlation p values for multiple comparisons using `stats::p.adjust(p, method = "fdr")`. To assess whether functioning variables explained unique variance in task performance, we also performed multiple regression in which functioning scores were the independent variables, and task scores were the dependent variable. Group differences and group by condition interactions were assessed via repeated measures analysis of variance using `afex::aov_ez()` (Singmann et al., 2023). Confidence intervals (CIs) for group difference effect sizes were computed using the MBESS package (Kelley, 2023). To assess mechanisms that might explain significant bivariate correlations and/or group differences, we conducted mediation analyses using 5,000 simulations with `mediate::mediate.pd(sims = 5000; Tingley et al., 2014)`.

Given well-known concerns about the reliability of difference scores (Cronbach & Furby, 1970), we computed split-half reliability of the Ebbinghaus context sensitivity scores (though for a defense of the reliability of difference scores; see Rogosa & Willett, 1983; Silverstein, 2008). We computed the correlation between context sensitivity scores derived from only even trials and context sensitivity scores from only odd trials and corrected the resulting coefficient

using the Spearman-Brown formula (Brown, 1910; Spearman, 1910). We were unable to assess the reliability of Mooney Faces performance because images did not repeat.

In addition to working directly with the manifest variables, we computed factor scores for a latent cognition factor and a latent social/role functioning factor. To do this, we entered the relevant manifest variables (HVLTL, WRAT, and BACS-SC scores for the latent cognition factor; global social functioning, global role functioning and social phobia scores for latent social/role functioning) into unifactor factor analyses. Estimated factor scores were then computed using the Thurstone (i.e. ordinary least squares regression) method (Bartholomew et al., 2009; Thomson, 1935). This process produced a set of estimated factor scores for a latent cognition factor and a set of estimated factor scores for a latent social/role functioning factor. We used these scores to assess whether each perceptual task was significantly more correlated with cognition or social/role functioning. To test whether correlation coefficients significantly differed from each other, we used the `run.co.cor.dep.groups.overlap` function from the `cocor` package (Diedenhofen & Musch, 2015) using the “`pearson1989`” method (though other methods gave similar results). Statistical analysis scripts (and corresponding raw output files) are publicly available (V. Pokorny, 2024).

Openness and Transparency Information

The data set is not open to the public at the time of writing; however, the data set will be publicly available through the National Institute of Mental Health Data Archive after study completion. Additional information regarding sample size determination, measures collected, and task manipulations can be found in a previously published report (Mittal et al., 2021). Previous publications have described aspects of this data set that are unrelated to the present article (Karp et al., 2023; Pratt et al., 2023; Rossi-Goldthorpe et al., 2024; Williams, Walker, et al., 2023). One previous publication (Silverstein et al., 2021) reported on group differences in some preliminary Mooney Faces data from this data set (37 CHR and 29 HC). Crucially, the primary results of the present article (i.e., full sample Ebbinghaus and Mooney Faces data and relationships with cognitive and social/role functioning) have not been published previously. Finally, there is another article from our group that examines (Tran et al., 2025) other aspects of the Mooney Faces task such as response bias and scrambled condition performance.

Results

Demographic Information

Demographic information for the sample is presented in Table 1. The sample consisted of 339 CHR, 162 PLE, 110 CLN, and 199 HC. Groups did not significantly differ in age or distribution of sex assigned at birth. However, the distribution of racial groups did significantly differ across study groups. Post hoc tests revealed that this significant omnibus effect was primarily driven by a smaller percentage of Asian participants in the CHR group and a greater percentage of Asian participants in the HC group. Groups did not differ with respect to the number of individuals identifying as Hispanic. Finally, the median household income differed across groups with the CLN and HC groups reporting higher incomes than the CHR and PLE groups. Information regarding medication and diagnostic status of the sample is presented in Supplemental Table 1 in the online supplemental materials. With respect to conversion rates, the collection of data is ongoing

and will be reported in a future publication. At the time of writing, however, the conversion rate is roughly 15%.

Group Differences in Cognitive, Social, and Role Functioning

As depicted in Table 2, groups differed with respect to cognitive, social, and role functioning. Specifically, we observed significant main effects of group for the BACS-SC, global functioning: role, global functioning: social, and Social Phobia Scale. We observed only marginal group differences in HVLTL performance and little to no group differences in WRAT performance. Follow-up *t* tests showed that CHR and PLE scored lower on the BACS-SC than HC, while HC and CLN did not significantly differ from each other. With respect to social and role functioning, CHR scored significantly lower than other groups, while CLN and HC did not significantly differ from each other. All groups differed on the Social Phobia Scale with CHR scoring highest and HC scoring the lowest.

Group Differences in Visuoperceptual Organization

For the Ebbinghaus task, we did not observe significant group differences in context sensitivity (see Table 2). In a previous report (Mittal et al., 2015), we observed reduced sensitivity in the misleading condition in CHR relative to HC when only looking at the hardest trials (i.e., 2% size difference trials). We were unable to replicate this effect, though mean values were in the expected direction with CHR values closer to zero (CHR: $M = -51.1$, HC: $M = -53.2$), $t(429) = -1.16$, $p = .124$, Cohen's $d = 0.06$. For the Mooney Faces task, we observed a significant group by condition interaction, $F(3, 640) = 9.6$, $p < .001$, $\eta^2 = .043$. This interaction was driven by the CHR group reporting more faces for the inverted faces condition, CHR vs. HC inverted faces: $t(423) = -3.91$, $p < .001$, Cohen's $d = -0.19$. Surprisingly, Ebbinghaus context sensitivity did not correlate significantly with detection of upright, $r(598) = .03$, $p = .529$, or inverted, $r(600) = .003$, $p = .932$, Mooney faces.

Relationships Between Ebbinghaus Performance and Functioning

The raw reliability coefficient of the Ebbinghaus context sensitivity index was .77 (95% CI [0.73, 0.8]), and the Spearman-Brown correction produced an estimated reliability of .87. Thus, context sensitivity reliability was acceptable, despite it being a difference-of-differences score. In terms of bivariate correlations, Ebbinghaus context sensitivity significantly correlated with BACS-SC, $r(572) = .13$, $p_{\text{fdr}} = .007$, 95% CI [0.05, 0.21], HVLTL, $r(608) = .1$, $p_{\text{fdr}} = .016$, 95% CI [0.02, 0.18], and WRAT scores, $r(550) = .09$, $p_{\text{fdr}} = .038$, 95% CI [0.01, 0.17]. For all three variables, higher levels of cognitive performance were associated with greater context sensitivity (see Figure 2). When cognitive variables were entered simultaneously as predictors of context sensitivity, BACS-SC significantly predicted context sensitivity, $b = 0.18$, $t(480) = 2.03$, $p = .04$, partial $r^2 = .009$, over-and-above the WRAT and HVLTL. The direction and effect size of the association between BACS-SC and context sensitivity held when restricting the analysis to the CHR group; however, the *p* value was only significant prior to adjustment for multiple comparisons, BACS-SC: $r(222) = .14$, $p_{\text{unadjusted}} = .036$, $p_{\text{fdr}} = .107$, 95% CI [0.01, 0.27]. Across all groups, context sensitivity did not significantly correlate with global social,

Table 1
Demographic Information

Demographic variable	CHR (n = 339)	PLE (n = 162)	CLN (n = 110)	HC (n = 199)	Statistics
Age	23.47 (4.28)	23.67 (4.22)	24.23 (3.83)	23.72 (4.15)	$F(3, 785) = 0.89, p = .446$
Sex (%)					$\chi^2(3) = 5.5, p = .139$
Female	66	63	66	57	
Male	34	37	34	43	
Race (%)					$\chi^2(18) = 38.99, p = .003$
African American	15.85	18	14.02	13.27	
American Indian	0.61	1.90	0.93	0.51	
Asian	17.07	21.52	23	37.24	
Caucasian	52.13	50.63	51.40	40.31	
Hawaiian	0.61	0	0	0.51	
Multiracial	10.67	5	8.41	7.65	
Not reported	3.05	3.16	1.87	0.51	
Hispanic (%)	16	15	16	9	$\chi^2(3) = 5.71, p = .126$
Household income	\$57,000	\$60,000	\$85,000	\$1,00,000	$\chi^2(3) = 31.04, p < .001$

Note. Post hoc tests showed that the significant difference in race distribution between groups was primarily driven by a significant difference in number of Asian participants in the CHR and HC groups. CHR = clinical high risk; PLE = psychotic-like experiences; CLN = nonpsychotic clinical group; HC = healthy control.

$r(640) = .05, p_{\text{fidr}} = .232, 95\% \text{ CI } [-0.03, 0.13]$, or role functioning, $r(642) = .06, p_{\text{fidr}} = .219, 95\% \text{ CI } [-0.02, 0.14]$. Similarly, context sensitivity did not significantly correlate with social phobia scores, $r(622) = -.06, p_{\text{fidr}} = .219, 95\% \text{ CI } [-0.14, 0.02]$. Thus, cognitive functioning variables, in particular the BACS-SC, related to context sensitivity while social and role functioning variables did not.

It is possible that increased attentional lapses are responsible for the observed association between reduced context sensitivity and cognitive variables. To test this hypothesis, we conducted a follow-up mediation analysis in which BACS-SC was entered as the independent variable, context sensitivity was entered as the dependent variable, and Ebbinghaus catch trial performance was entered as the mediator variable. We observed a significant average causal mediation effect (ACME: $b = 0.05, 95\% \text{ CI } [0.01, 0.09], p = .004$). Thus, the association between BACS-SC performance and context sensitivity (i.e., total effect) was significantly reduced when catch trial performance was entered as a mediating variable. We observed a similar mediation effect when HVLT or WRAT scores were used as the independent variable (see Figure 3; WRAT: ACME $\beta = 0.06, 95\% \text{ CI } [0.02, 0.1], p < .001$; HVLT: ACME: $\beta = 0.22, 95\% \text{ CI } [0.11, 0.35], p < .001$).

Relationships Between Mooney Faces Performance and Functioning

To reduce the number of comparisons, we only assessed the associations between functioning and the inverted condition of the Mooney Faces task. This condition is more ambiguous, and thus, we expected more individual differences to be elicited. Furthermore, this is the condition that most strongly differentiated between CHR and HC. Greater inverted face reports were associated with poorer global role functioning, $r(638) = -.16, p_{\text{fidr}} < .001, 95\% \text{ CI } [-0.23, -0.08]$, and higher social phobia scores, $r(616) = .14, p_{\text{fidr}} = .001, 95\% \text{ CI } [0.06, 0.22]$. Global social functioning also related to inverted face reports, though the effect was weaker than global role functioning, $r(636) = -.09, p_{\text{fidr}} = .025, 95\% \text{ CI } [-0.17, -0.01]$. When entered simultaneously as predictors, greater social phobia, $b = 0.053, t(606) = 2.21, p = .03, \text{ partial } r^2 = .008$, and poorer role functioning, $b = -0.881, t(606) = -3.24, p < .001, \text{ partial } r^2 = .017$, significantly predicted more inverted face reports. Thus, these variables explained unique variance in task performance. We did not observe any bivariate correlations with cognitive variables ($ps > .461$).When restricting to the

Table 2
Group Differences on Primary Variables

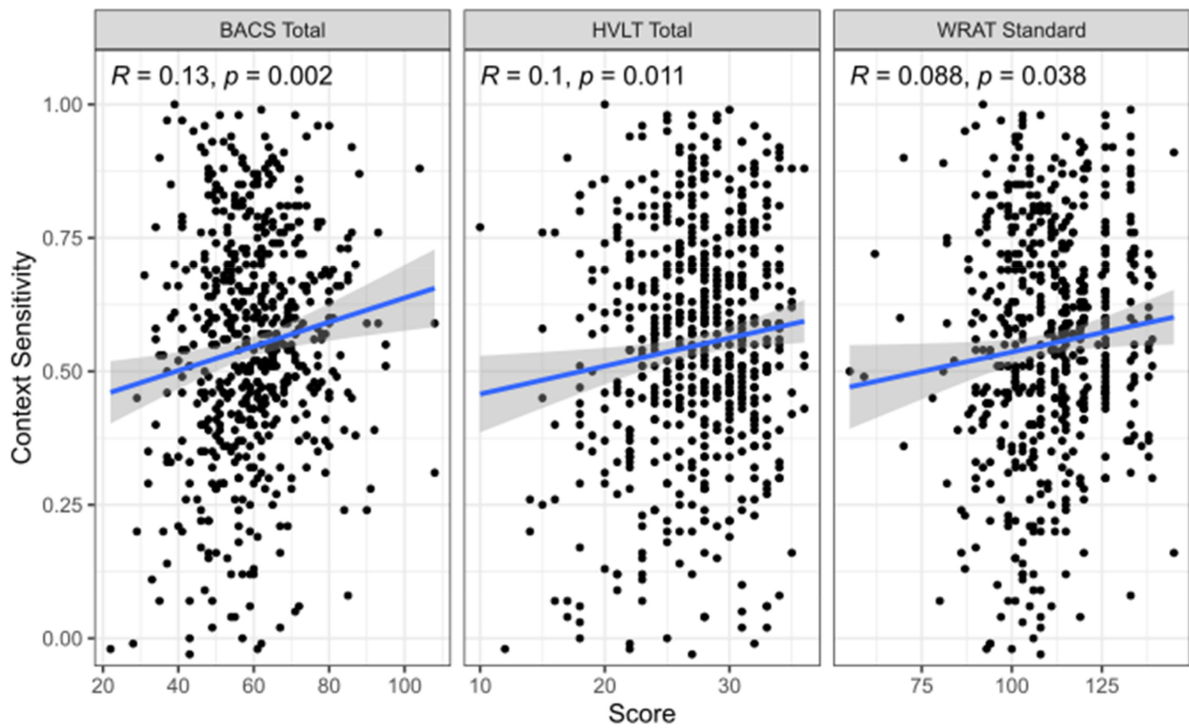
Dependent variable	CHR	PLE	CLN	HC	Statistics	Post hoc (FDR corrected)
Cognitive						
BACS-SC total	57.52 (12.97)	58.18 (12.08)	59.82 (11.9)	62.9 (12.83)	$F(3, 662) = 6.69, p < .001$	CHR, PLE < HC
HVLT total	26.6 (4.69)	26.47 (4.86)	27.31 (4.77)	27.62 (4.21)	$F(3, 739) = 2.61, p = .051$	
WRAT standard	110.02 (14.38)	109.53 (13.97)	110.8 (13.62)	110.7 (14.6)	$F(3, 672) = 0.24, p = .868$	
Social/role						
Global functioning: role	7.46 (1.86)	8.05 (1.45)	8.64 (1.1)	8.96 (0.89)	$F(3, 783) = 46.44, p < .001$	CHR < PLE < CLN, HC
Global functioning: social	7.28 (1.39)	7.68 (1.29)	8.32 (1.02)	8.52 (1.01)	$F(3, 779) = 47.41, p < .001$	CHR < PLE < CLN, HC
Social Phobia Scale	28.25 (18.6)	22.25 (15.51)	15.54 (12.07)	9.3 (8.27)	$F(3, 726) = 64.66, p < .001$	CHR > PLE > CLN > HC
Task						
Context sensitivity	54.4 (22.56)	51.61 (25.4)	53.66 (22.99)	56.66 (22.68)	$F(3, 645) = 1.18, p = .315$	
Upright faces reported	34.06 (5.89)	33.45 (4.85)	33.04 (5.7)	33 (5.93)	$F(3, 641) = 1.46, p = .223$	
Inverted faces reported	15.93 (9.56)	12.53 (8.16)	11.38 (8.41)	12.19 (9.47)	$F(3, 642) = 9.44, p < .001$	CHR > PLE, CLN, HC

Note. CHR = clinical high risk; PLE = psychotic-like experiences; CLN = nonpsychotic clinical group; HC = healthy control; FDR = false discovery rate; BACS-SC = Brief Assessment of Cognition in Schizophrenia Symbol Coding; HVLT = Hopkins Verbal Learning Test-Revised; WRAT = Wide Ranging Achievement Test.

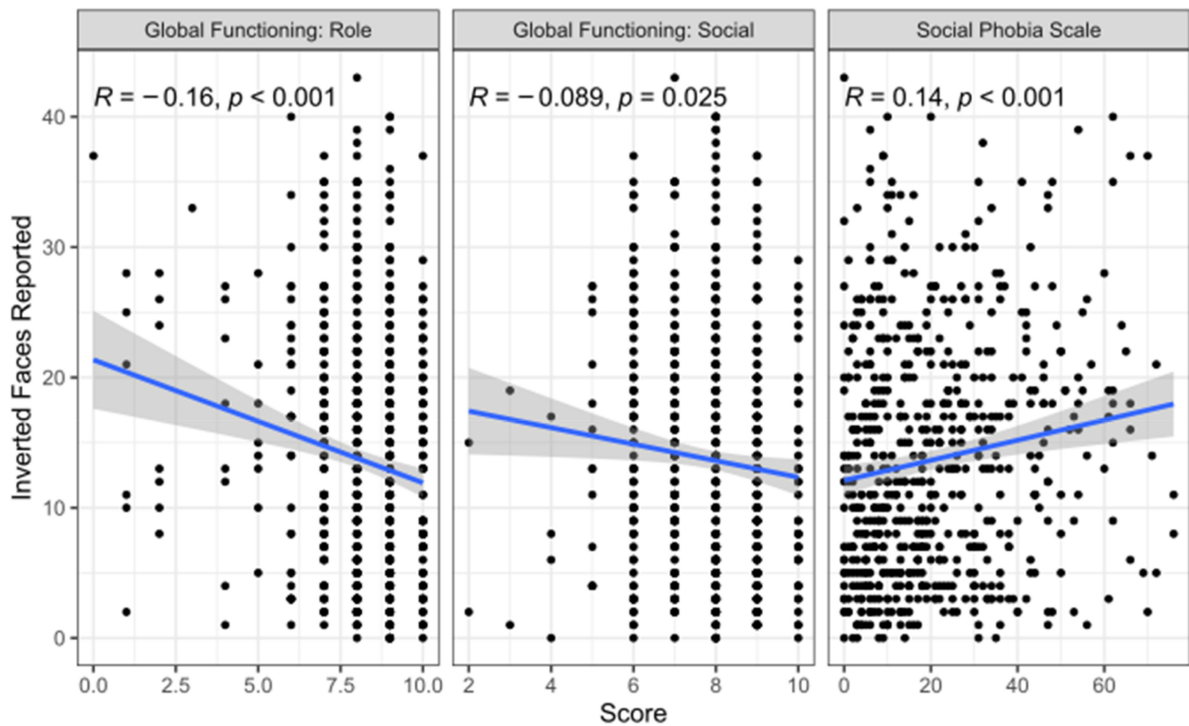
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Figure 2
Relationships Between Visual Perception and Cognitive, Social, and Role Variables

A.



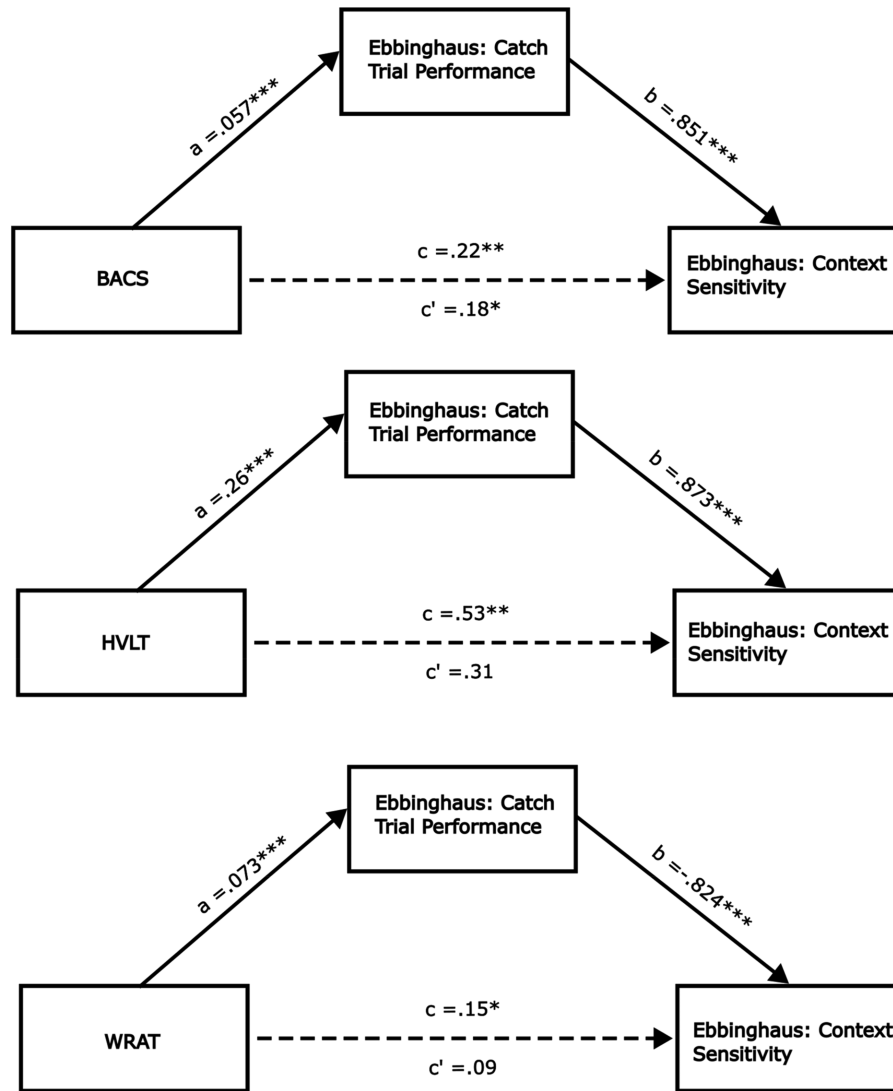
B.



Note. (A) Ebbinghaus and cognitive variables. (B) Mooney faces and social/role variables. BACS = Brief Assessment of Cognition Symbol Coding; HVL = Hopkins Verbal Learning Test-Revised; WRAT = Wide Ranging Achievement Test. See the online article for the color version of this figure.

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Figure 3
Catch Trial Performance Mediates the Association Between Cognition and Context Sensitivity



Note. c indicates the total effect coefficient and c' indicates the direct effect coefficient (i.e., total effect—indirect effect). BACS = Brief Assessment of Cognition Symbol Coding; HVL = Hopkins Verbal Learning Test-Revised; WRAT = Wide Ranging Achievement Test.

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

CHR group only, the association with role functioning remained significant, $r(262) = -.18$, $p_{\text{fdr}} = .009$, 95% CI $[-0.29, -0.06]$, while the associations with social phobia $r(250) = .12$, $p_{\text{fdr}} = .06$, 95% CI $[0, 0.24]$, and social functioning, $r(262) = -.12$, $p_{\text{fdr}} = .06$, 95% CI $[-0.24, 0]$, became marginal.

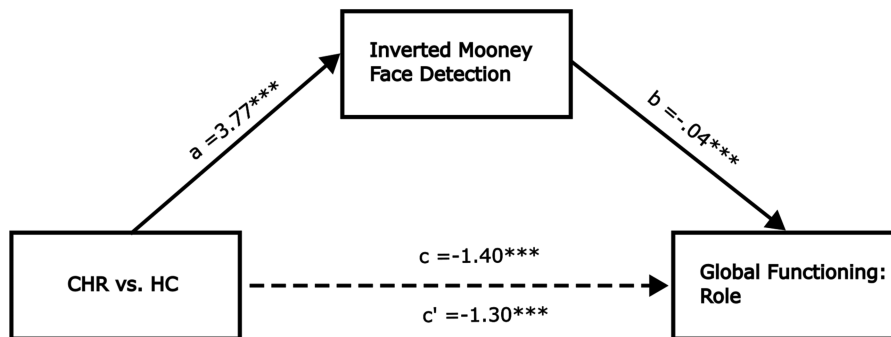
We conducted a follow-up mediation analysis to test whether Mooney Faces task performance could explain group differences in downstream role dysfunction. In the mediation model, group was entered as the independent variable, inverted face reports were entered as the mediator, and global role functioning was entered as the dependent variable. For this model, the binary group variable was coded such that CHR subjects were the treatment level, and HC were the control level. Inverted face reports significantly mediated the relationship between group and role functioning (ACME: $b = -0.1$, 95% CI

$[-0.18, -0.03]$, $p = .001$). Thus, the group difference in role functioning between CHR and HC status was significantly reduced when atypical inverted face responses were entered as a mediating variable. This effect is consistent with atypical visual processing in CHR explaining poorer downstream role functioning (see Figure 4).

Reaction Time and Nonresponding

There were no group differences in mean reaction time for either task, Ebbinghaus: $F(3, 640) = 1.59$, $p = .192$, Mooney: $F(3, 636) = 0.31$, $p = .82$. For Mooney Faces, there was a marginal difference between groups in the number of trials missed due to not responding within the task's time window, $F(3, 641) = 2.38$, $p = .069$. This group difference effect was slightly stronger, but significant, for the

Figure 4
Role Functioning Mediates Association of CHR Status and Face Detection



Note. *c* indicates the total effect coefficient and *c'* indicates the direct effect coefficient (i.e., total effect–indirect effect). CHR = clinical high risk; HC = healthy control.
 *** $p < .001$.

Ebbinghaus task, $F(3, 636) = 2.68, p = .046$. This difference was primarily driven by more nonresponding in the CHR group. The associations between context sensitivity and cognition measures remained significant after controlling for nonresponding, BACS-SC: $b = 0.054, t(558) = 2.13, p = .033, \text{partial } r^2 = .008$, HVL: $b = 0.021, t(594) = 2.4, p = .017, \text{partial } r^2 = .01$, WRAT: $b = 0.056, t(537) = 1.97, p = .05, \text{partial } r^2 = .007$.

Latent Variable Scores

To further demonstrate the differential associations between the visuoperceptual organization tasks and functioning, we entered the cognition and social/role variables into separate unifactor factor analysis models and estimated latent factor scores. The correlation between true factor scores and estimated factor scores (i.e., the degree of factor score determinacy) was .81 for cognitive scores and .82 for social/role scores. As expected, Ebbinghaus context sensitivity significantly correlated with the latent cognition scores, $r(460) = -.16, p = .001, 95\% \text{ CI } [-0.25, -0.07]$, but not the latent social/role scores, $r(460) = .06, p = .17, 95\% \text{ CI } [-0.03, 0.15]$, and inverted Mooney face reports correlated significantly with latent social/role scores, $r(456) = -.16, p < .001, 95\% \text{ CI } [0.07, 0.25]$, but not the latent cognition scores, $r(456) = -.03, p = .579, 95\% \text{ CI } [-0.12, 0.06]$. Finally, context sensitivity correlated significantly more with cognition scores than social/role scores ($z = -3.00, p = .003$) and inverted Mooney Faces performance correlated significantly more with social/role scores than cognition scores ($z = -2.55, p = .011$).

Discussion

Summary

The present study examined visuoperceptual organization in a CHR sample. In particular, we were interested in the relationship between perceptual organization and cognitive, social, and role functioning. The strengths of the present study include a large sample size, two measures of perceptual organization, and a sample that spans a spectrum of psychotic and nonpsychotic psychopathology. We observed differential associations for the two visual tasks: Ebbinghaus context sensitivity predicted cognitive functioning, while Mooney Faces performance predicted social/role functioning. Mooney Faces task

performance significantly differed between CHR and HC, while Ebbinghaus context sensitivity did not. These results suggest that perceptual closure during face processing may be more directly related to clinical risk for psychosis than contextual modulation of size perception; however, we note that a previous report from our group linked CHR status to reduced context sensitivity on the Ebbinghaus task (Mittal et al., 2015).

Mooney Face Detection and Role Functioning

Responses to the inverted Mooney Faces condition were most strongly predicted by role functioning. Furthermore, the differing task performance of CHR and HC in this condition was significantly explained by role functioning scores. In what follows, we speculate on possible mechanisms that can explain this pattern of results.

We hypothesize that greater detection of inverted faces reflects an overweighting of perceptual and/or cognitive priors. When viewing ambiguous inverted images, individuals with stronger priors will report seeing more faces. It is possible that, in addition to affecting task performance, overweighting of perceptual priors may lead to atypical perceptual experiences (e.g., perception of illusory figures, shapes, and objects during naturalistic real-world visual experiences). Such experiences could in turn impair functioning in school and workplace settings. Alternatively, overweighting of priors may occur at a higher, cognitive level instead of the perceptual level. Successful navigation of school and workplace settings also requires balancing preexisting beliefs with novel incoming evidence from teachers, peers, and supervisors. In particular, individuals with strong cognitive priors may struggle to adjust behaviors based on outside contradictory testimony.

The foregoing account assumes (a) that performance on the Mooney faces task is due to overweighting of priors and (b) that overweighting of priors causally influences role functioning. A more parsimonious explanation might be that motivational and task engagement factors are causally driving both poor role functioning and altered Mooney faces task performance. However, it is unclear how reduced motivation or task engagement would lead to greater face detection in the more ambiguous condition. Furthermore, the lack of significant associations with cognitive assessments wherein motivation and engagement would play a substantial role also suggests that our pattern of results is difficult to

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explain in terms of reduced motivation or task engagement. Other mechanisms such as heightened perceptual sensitivity may also explain altered performance on the Mooney Faces task in CHR. Another article from our group (Tran et al., 2025) discusses these possible mechanisms.

As pointed out by an anonymous peer reviewer, it is, perhaps, surprising that Mooney Faces performance was more strongly associated with role functioning rather than social functioning. Indeed, social interactions often involve perception of facial features. In particular, facial expressions are thought to act as “social-tools that modify the trajectory of our social interactions” (Fridlund & Russell, 2006, p. 299). We speculate that Mooney Faces task performance was less strongly tied to social functioning because the task does not require participants to infer emotional content or meaning of facial expressions. Future work might explore whether a Mooney Faces task that manipulates facial emotions of the images relates more strongly to social functioning.

Mooney Faces and Social Phobia

We observed a significant relationship between inverted Mooney Face reports and social phobia severity. We are unaware of any previous reports of this association; however, there are published reports of differential processing of faces in individuals with social anxiety (Bögels & Mansell, 2004; Kishimoto et al., 2021; McTeague et al., 2018). In particular, individuals with social anxiety are thought to show heightened vigilance for faces, especially for negative faces. Thus, our finding of greater inverted face detection in individuals with greater social phobia scores may reflect heightened vigilance for faces due to social anxiety.

Context Sensitivity and Cognition

We did not observe differences in context sensitivity between groups, but we observed associations between cognitive functioning and context sensitivity. Visuospatial size illusions are thought to arise from an adaptive need to efficiently infer three-dimensional percepts from two-dimensional retinal inputs (Yildiz et al., 2022). Thus, a lack of sensitivity to such illusions may reflect inefficient processing of visual information. Such perceptual inefficiencies may cause, or be caused by, higher level cognitive inefficiencies.

Another possibility is that this association is simply driven by attentional lapses. Higher attentional lapse rates, perhaps due to a generalized cognitive deficit, can lead to reduced context sensitivity measurements. Indeed, completely random responding could be interpreted as complete imperviousness to context. Similarly, individuals who experience more attentional lapses, all else being equal, will perform more poorly on cognitive assessments. Fortunately, lapse rates can be estimated from catch trial performance. We found that catch trial accuracy significantly mediated the association between cognition and context sensitivity. This is consistent with the hypothesis that attentional lapsing may explain some of the association between cognition and context sensitivity. Having said this, attentional lapses only explained about 20%–40% of the association between context sensitivity and cognition such that other factors, such as inefficient processing of visual information, may also contribute to the association.

It is also possible to interpret Ebbinghaus illusion susceptibility in terms of Bayesian inference wherein reduced susceptibility to the

illusion is thought to reflect weakened perceptual priors for perspective/distance cues (Doherty et al., 2010), though also see Todorovic and Jovanovic (2018). Interpreted this way, underweighting of perspective/distance priors, as measured by the Ebbinghaus task, was associated with poorer cognitive functioning, while overweighting of face perception priors, as measured by the Mooney Faces task, predicted poorer social/role functioning. Importantly, given the lack of correlation between these two tasks, the strength of priors for size perception and strength of priors for face perception appear to be largely independent of one another. This is not wholly surprising given size perception and face perception are thought to recruit differing neural mechanisms (McKeeff & Tong, 2007; Schwarzkopf et al., 2011).

Mechanisms of Mooney Faces and Ebbinghaus Illusion

Given the differential associations with group status and functioning measures, it is worth further considering the different perceptual and neural mechanisms tapped by these two tasks. The Ebbinghaus illusion is a visuospatial context illusion. There is a large body of evidence linking psychotic disorders to atypical use of visuospatial context during perception of contrast, motion, lightness, orientation, and contours (Chen et al., 2008; Dakin et al., 2005; V. J. Pokorny et al., 2021, 2023; Tibber et al., 2013; Yang et al., 2013). However, a recent meta-analysis found that evidence for a general visuospatial context processing impairment in psychotic disorders is weak (V. J. Pokorny et al., 2024). With respect to size illusions specifically, this meta-analysis found only weak evidence of atypical context processing in psychotic disorders. Thus, the lack of group differences between CHR and controls observed in the present study may not be entirely out of keeping with the published evidence, though clearly more research is required. Although the neural mechanisms of the Ebbinghaus illusion are still under investigation, recent work has shown that the surface area of V1 (Schwarzkopf et al., 2011) correlates with magnitude of the illusion. This is thought to provide evidence for a biphasic contour interaction account of the illusion (Urale & Schwarzkopf, 2023), which posits that contours close to one another (both in terms of visual space and cortical distance in V1) are attractive, whereas contours distant from one another are repellent.

The Mooney Faces task is a measure of perceptual closure which is defined by Mooney (1957) as “the perception of an object or event that is not completely or immediately represented” (p. 219). Perceptual closure is thought to arise from the adaptive need to make inferences about the state of the world from incomplete and noisy sensory evidence. Similar to Bayesian inference accounts of perception, closure is thought to be accomplished through use of prior perceptual knowledge (Schwiedrzik et al., 2018). In terms of neural mechanisms, FFA activation is strongly linked with both perception of faces generally (Kanwisher & Yovel, 2006) and perception of Mooney Faces specifically (McKeeff & Tong, 2007). Furthermore, perception of Mooney Faces is associated with an increase in brain-wide long-distance gamma band synchronization (Rodriguez et al., 1999). Thus, our results suggest that greater perceptual closure for inverted faces in CHR may reflect altered FFA activation and/or gamma band synchronization. This altered FFA hypothesis is consistent with work from Silverstein et al. (2010) in which individuals with schizophrenia exhibited altered FFA activation when viewing spatially filtered pictures of faces. Future work should clarify the degree to which such neural mechanisms are altered in CHR. Doing so may illuminate novel, clinically useful biomarkers of psychosis risk.

Limitations

Some methodological limitations must be noted. First, the visuo-perceptual organization tasks did not control fixation, which may have led to heterogeneity in viewing strategies across individuals. We chose not to control fixation because we hoped to encourage naturalistic viewing that might better generalize to real-world visual experiences. Another limitation is that viewing distance, room lighting, and monitor type differed across subjects, which likely inflated measurement noise. Recent work has shown that the Ebbinghaus illusion is robust to variability in viewing environments (Krantz, 2021). Indeed, the author concludes “that stimuli and visual phenomena based on high contrast images where the effect is dependent upon relationships within the stimuli ought to be successfully studied online” (p. 233). Based on this reasoning, both tasks reported should be relatively robust to (reasonable) variations in viewing distance and absolute size. Still, further work is needed to assess the translatability of visuo-perceptual tasks to online contexts.

In our sample, CHR status did not significantly predict context sensitivity. This lack of group difference is surprising given previous work from our group in which CHR exhibited reduced context sensitivity, particularly in the misleading condition (Mittal et al., 2015). There are a number of factors that may have contributed to our inability to replicate previously observed effects. First, the sample size of the original study (19 CHR and 19 HC) was roughly an order of magnitude smaller than the present study (340 CHR, 199 HC). Small sample sizes can produce large effect sizes by chance. Thus, it is possible that the true effect size is simply smaller than previously estimated. Additionally, the 2015 study collected data in a controlled psychophysics environment. As mentioned in the previous paragraph, the lack of control over the experimental environment in the present study may have introduced additional measurement noise, which may have attenuated effect sizes. Finally, a previous report found that individuals with chronic schizophrenia admitted to a short-term inpatient treatment center exhibited reduced context sensitivity at intake but typical context sensitivity at discharge (Silverstein et al., 2013). This suggests that the degree of context sensitivity may be a state marker of symptom severity. Thus, in the case of CHR, the degree of illness may be too mild for the Ebbinghaus illusion to reliably differentiate between CHR and HC.

Conclusion

Our findings suggest that distinct aspects of visuo-perceptual organization exhibit differential associations with functioning across the CHR spectrum. Furthermore, only perceptual closure, as measured by the Mooney Faces task, was significantly altered in CHR. Further studies of the neural and perceptual mechanisms of this effect are warranted. Moreover, a crucial next step of the present work will be to test whether these visuo-perceptual organization tasks predict longitudinal change in functioning, which will further clarify the clinical utility and validity of these computerized assessments.

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