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Early Visual Processing Is Associated With Social Cognitive Performance in Recent-Onset Schizophrenia

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Background: Early-stage visual processing deficits are evident in chronic schizophrenia. Consistent with a cascade model of information processing, whereby early perceptual processes have downstream effects on higher-order cognition, impaired visual processing is associated with deficits in social cognition in this clinical population. However, the nature of this relationship in the early phase of illness is unknown. Here, we present data from a study of early visual processing and social cognitive performance in recent-onset schizophrenia (ROSz).

Method: Thirty-two people with ROSz and 20 healthy controls (HC) completed a visual backward masking task using stimuli of real world objects (Object Masking) to assess early-stage (i.e., 0–125 ms post-stimulus onset) visual processing. Subjects also completed two tasks of social cognition, one assessing relatively low-level processes of emotion identification (Emotion Biological Motion, EmoBio), and another assessing more complex, higher-order theory of mind abilities (The Awareness of Social Inference Test, TASIT). Group differences were tested with repeated measures ANOVAs and *t*-tests. Bivariate correlations and linear regressions tested the strength of associations between early-stage visual processing and social cognitive performance in ROSz.

Results: For Object Masking, the mask interfered with object identification over a longer interval for ROSz than for HC [F (3.19, 159.35) = 8.51, $p < 0.001$]. ROSz were less accurate on the EmoBio task [t (50) = –3.36, $p = 0.001$] and on the TASIT compared to HC [F (1, 50) = 38.37, $p < 0.001$]. For the TASIT ROSz were disproportionately impaired on items assessing sarcasm detection [F (1, 50) = 4.30, $p = 0.04$]. In ROSz, better Object Masking performance was associated with better social cognitive performance [$r_{\text{EmoBio}} = 0.45$, $p < 0.01$; $r_{\text{TASIT}} = 0.41$, $p < 0.02$]. Regression analyses did not provide significant support for low-level social cognition mediating the relationship between visual processing and high-level social cognition.

Conclusion: Early-stage visual processing, low-level social cognition, and high-level social cognition were all significantly impaired in ROSz. Early-stage visual processing was

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associated with performance on the social cognitive tasks in ROSz, consistent with a cascade model of information processing. However, significant cascading effects within social cognition were not supported. These data suggest that interventions directed at early visual processing may yield downstream effects on social cognitive processes.

Keywords: visual perception, backward masking, theory of mind, emotion identification, first episode psychosis

INTRODUCTION

Schizophrenia is associated with marked impairment across a variety of information processing domains, spanning from very early stages of perceptual processing, through complex, higher-order cognitive processes. Deficits in early-stage visual processing have consistently been reported in chronic schizophrenia (1–6). Consistent with a cascade model of information processing, whereby disruptions in early perceptual processes have downstream consequences for higher-order cognition and functioning, impaired visual processing is associated with deficits in social cognition (i.e., processing of social stimuli including emotion identification and mental state attribution) in this clinical population (7–14). Moreover, structural equation modeling analyses have demonstrated that social cognition mediates the relationship between visual processing and community functioning in people with schizophrenia (7, 12, 15). Thus, visual processing and social cognitive abilities are important components of the pathway toward functional recovery in schizophrenia.

Social cognitive deficits are well-documented in people with recent-onset schizophrenia (ROSz), with meta-analytic reviews reporting large effect sizes that are on par with those obtained from chronic phase schizophrenia samples (16–18). In contrast, considerably less is known about visual perception abnormalities in the early phase of illness. Similarly, the nature of the relationship between visual processing and social cognition in the early phase of illness is unknown. The available evidence strongly suggests visual processing abnormalities in ROSz (19–23), with patients exhibiting significantly impaired contour integration (19), visual perception organization (20), and motion processing (21) relative to healthy adults. However, the magnitude of impairment may be attenuated relative to what is observed in chronic phase schizophrenia (19, 24, 25).

The earliest stages of visual processing can be probed behaviorally with visual masking tasks (see (26) for a comprehensive review). In these tasks, a rapidly presented target stimulus is either shortly preceded by (for forward masking) or shortly followed by (for backward masking) a masking stimulus which interferes with processing of the target. Depending on the type of paradigm used, the masking stimuli may spatially overlap the target, or it may surround, but not touch, the target. The duration of the interval between the target and mask is brief (i.e., 0–500 ms), and is varied across trials. Accuracy for identifying the target, or some aspect of the target (e.g., target location, a feature of the target), is assessed yielding a masking function. For backward masking, the typical response function is S-shaped, with very poor accuracy at short intervals between target and mask, and improved performance as the interval between target and mask increases.

Prior studies of visual backward masking in ROSz indicate impaired performance relative to healthy adults (22, 25), an association with duration of untreated psychosis (i.e., short duration of untreated psychosis associated with better performance; (27)), and stability of performance over 6–24 months (22, 23). Here, we assessed visual backward masking and test the association between early visual processing and performance on social cognitive tasks that involve processing of visual cues in people with ROSz and healthy adults. We hypothesized that visual backward masking performance and social cognitive task performance would be significantly impaired in the ROSz sample compared to healthy adults. In addition, we hypothesized that visual backward masking performance would be significantly correlated with social cognitive task performance in the patient group.

METHOD

Participants

Thirty-two people with recent-onset schizophrenia (ROSz) and 20 healthy controls (HC) participated in this study. The patient participants were recruited from the UCLA Aftercare Research Program, an outpatient research clinic for ROSz. Inclusion criteria were: 1) onset of a first psychotic episode within 24 months of program entry, 2) fulfillment of DSM-IV (28) criteria for schizophrenia, schizoaffective disorder, depressed type, or schizophreniform disorder, 3) age of 18 to 45 years, and 4) sufficient fluency in English to allow for valid completion of the testing protocol. These participants met criteria for schizophrenia (n = 24), schizoaffective disorder, depressed type (n = 3), or schizophreniform disorder (n = 5). All ROSz participants were prescribed atypical antipsychotic medication, and chlorpromazine (CPZ) equivalent dosing information (29, 30) can be found in **Table 1**.

The HC sample were recruited *via* advertisements (e.g., online classified ads, flyers in the community), and had no current psychiatric diagnosis, no lifetime history of any psychotic disorder, bipolar disorder, or recurrent depressive disorder, and no history of a psychotic disorder among their first degree relatives. For all subjects, current substance or alcohol use disorder, history of head injury with loss of consciousness, seizure disorder, and/or IQ below 70 were exclusionary. Demographic information for the study participants is presented in **Table 1**.

TABLE 1 | Demographic characteristics of the study participants.

	ROSz (n = 32) n (%)	HC (n = 20) n (%)	χ^2 (df), p-value
Gender (male)	22 (69%)	15 (75%)	χ^2 (1) = 0.23, p = 0.63, Cramer's V = 0.02
Race			
Caucasian	10 (31%)	6 (30%)	χ^2 (4) = 1.99, p = 0.74, Cramer's V = 0.20
African American	8 (25%)	4 (20%)	
Asian	2 (6%)	2 (10%)	
Native American	0 (0%)	1 (5%)	
Other	12 (38%)	7 (35%)	
Ethnicity (Hispanic)	14 (44%)	10 (50%)	χ^2 (1) = 0.02, p = 0.89, Cramer's V = 0.06
	mean (s.d.)	mean (s.d.)	t(df), p-value
Age	23.71 (4.07)	23.05 (2.89)	t(50) = 0.63, p = 0.53, Cohen's d = 0.18
Personal education	12.29 (1.40)	14.50 (1.36)	t(49) = −5.58, p < 0.001, Cohen's d = −1.59
Parental education	14.34 (3.97)	14.15 (3.07)	t(47) = 0.19, p = 0.85, Cohen's d = 0.06
MCCB neurocognitive composite score	28.73 (15.76)	48.16 (6.60)	t(50) = 6.20, p < 0.001, Cohen's d = 1.75
BPRS positive symptoms	13.28 (6.13)		
BPRS negative symptoms	6.56 (3.38)		
BPRS total score	37.13 (9.94)		
Antipsychotic medication dosing (CPZ equivalents)	304.94 (143.82)		

Clinical and Cognitive Characterization

DSM-IV diagnoses were made using the Structured Clinical Interview for DSM-IV (SCID) (31) and SCID-II (32). For the patient sample, current (i.e., within the 2 week period prior to testing) psychiatric symptoms were assessed by trained raters with the 24-item Brief Psychiatric Rating Scale (BPRS) (33). Each clinical rater achieved a median Intraclass Correlation Coefficient (ICC) of 0.80 or higher across all BPRS items compared with the criterion ratings and participated in a quality assurance program (34). For the SCID, clinical raters demonstrated an overall kappa coefficient, kappa sensitivity, and kappa specificity of 0.75 or greater, and a diagnostic accuracy kappa coefficient of 0.85 or greater. For all participants, cognitive performance was assessed using the MATRICS Consensus Cognitive Battery (MCCB) (35). The variable of interest was the age and gender-corrected neurocognitive composite score, which reflects performance on tasks assessing speed of processing, attention/vigilance, working memory, verbal learning, visual learning, and reasoning and problem solving.

Visual Processing

All participants completed a backward masking task using common household objects as targets ("Object Masking"; see **Figure 1**) (36). The task was run in Eprime (Psychology Software Tools, Inc., Sharpsburg, PA, USA) on a Dell Alienware Aurora R4 Intel Core i7 PC, using a Nvidia GeForce GTX 560 Ti video card. All stimuli were presented on a 120 Hz Asus V0236 LCD 23" monitor. Target stimuli from one of six different objects were presented for 8 ms. Target stimuli were followed by a masking stimulus (overlapping black and white curved lines that spatially overlapped the target location) that was presented for 75 ms after a variable inter-stimulus interval (ISI) of 8–125 ms (in 17 ms increments). There were 12 trials per ISI, plus 12 unmasked trials (i.e., target was presented without a mask). After each trial, a list of the six objects appeared and participants verbally reported which object they thought the target was and the tester entered the response into the computer. Because participants gave verbal responses, reaction times were not recorded. The dependent measure was accuracy, measured as proportion correct. Mean accuracy across ISIs was the variable of interest for the correlation and regression analyses (10).

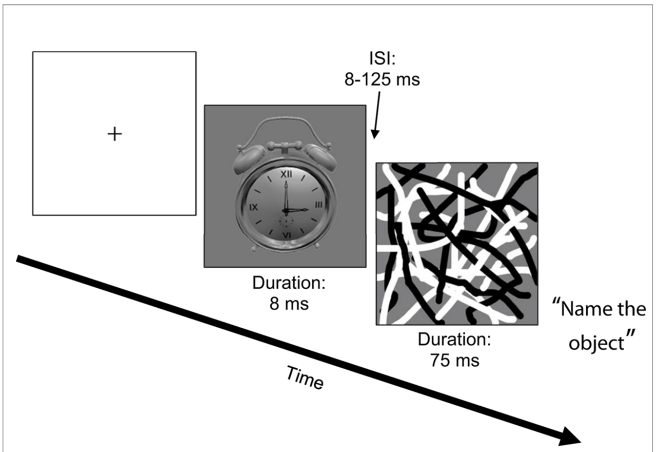

FIGURE 1 | Object Masking task.

Social Cognition

Low-level emotion identification was assessed with Emotion in Biological Motion (EmoBio) (37), and higher-order theory of mind abilities were assessed with Part 3 of The Awareness of Social Inference Test (TASIT) (38). For EmoBio, the ability to perceive emotion based on limited cues from body motion (i.e., gait, limb movement, speed of movement) was assessed using the point-light walker stimuli (39) and adapted for clinical trials use (37). Twenty-four point-light walker clips of 5–10 s in length were presented on a computer screen. Participants were asked which of five emotional states (fear, anger, happiness, sadness, or neutral) best described the movement of the walker. The five choices for emotional state were presented on the computer screen immediately after presentation of the clip. The dependent measure was accuracy, measured as proportion correct.

The TASIT Part 3 is comprised of 16 audio-video vignettes of adults interacting with each other. After each vignette, participants respond to four yes/no questions probing the beliefs and intentions of the characters. Half of the vignettes involve a character lying to another character, and half of the vignettes involve a character making sarcastic comments.

Participants detect lies and sarcasm based on integration of multiple sources of social information including facial affect, vocal prosody, body motion, mental state attributions, social knowledge, and contextual cues. The dependent measure was accuracy, measured as proportion correct for the Lies and Sarcasm conditions.

Data Analysis

The data were screened for univariate outliers using box plots, and for skewness with histograms. Group differences for the visual processing and social cognition tasks were tested with repeated measures ANOVAs and *t*-tests. When assumptions of sphericity were violated in the repeated measures analyses, a Greenhouse-Geisser correction was used. Bonferroni corrections were used to control the familywise error rate of the *post-hoc* analyses. For the *post-hoc* paired *t*-tests of the Object Masking data, critical $\alpha = 0.05/14$ tests or 0.004. For *post-hoc t*-tests of the TASIT data, critical $\alpha = 0.05/4$ tests or 0.01. In the ROSz group, bivariate correlations and multiple linear regression (method = enter) tested the strength of associations between early-stage visual processing and social cognitive task performance. For the regression analyses, the data were screened for multivariate outliers using Mahalanobis distances (critical $\alpha = 0.001$). Effect sizes were interpreted as small ($r = 0.10$, partial $\eta^2 = 0.01$, Cohen's $d = 0.20$), medium ($r = 0.30$, partial $\eta^2 = 0.09$, Cohen's $d = 0.50$), or large ($r = 0.50$, partial $\eta^2 = 0.25$, Cohen's $d = 0.80$) (40, 41).

RESULTS

Sample Characteristics

Demographic, clinical, and cognitive characteristics of the study participants are presented in **Table 1**. The two groups were well-matched on demographic characteristics, including age, gender, race and ethnicity, and level of parental education. Twenty-two (69%) of the ROSz participants met criteria for positive symptom remission (i.e., score of ≤3 on BPRS hallucinations, unusual thought content, and conceptual disorganization) for the 2 week period prior to testing (42). As expected, the ROSz participants exhibited significant neurocognitive impairment relative to the HC group [t (50) = 6.20, $p < 0.001$, Cohen's $d = 1.75$]. The magnitude of impairment was similar to our previous findings with a different ROSz patient cohort (43).

Visual Processing

Results for the Object Masking task are presented in **Figure 2** and **Table 2**. Mean accuracy (i.e., proportion correct) for the unmasked control condition exceeded 0.90, and performance did not significantly differ between groups [$p = 0.12$, Cohen's $d = 0.47$]. Data for the individual ISIs were negatively skewed, as is typical for backward masking tasks, and were thus log transformed prior to repeated measures analysis. Across ISIs, a typical backward masking response profile was evident [main effect of ISI: F (3.19, 159.35) = 44.08, $p < 0.001$, partial $\eta^2 = 0.47$]. Accuracy was poor at brief ISIs [8 ms ISI mean accuracy = 0.32, *s.d.* = 0.25], indicating that the mask interfered with processing of the target stimulus, and performance steadily improved as the ISI duration increased [125 ms ISI mean accuracy = 0.94, *s.d.* = 0.14], reflecting escape from the masking effect.

The interference by the mask was greater in ROSz compared to HC [group × ISI: F (3.19, 159.35) = 8.51, $p < 0.001$, partial $\eta^2 = 0.15$]. For the HC group, follow-up paired *t*-tests indicated that accuracy significantly improved between 25 and 42 ms ISI [t (19) = 6.52, $p < 0.001$, Cohen's $d = 1.45$], but tapered off between 42 and 58 ms ISI [t (19) = 1.87, $p = 0.07$, Cohen's $d = 0.19$], reflecting escape from the masking effect. Compared to HC, the ROSz group exhibited worse performance across ISIs [group: F (1, 50) = 5.76, $p = 0.02$, partial $\eta^2 = 0.10$]. Follow-up paired *t*-tests indicated that

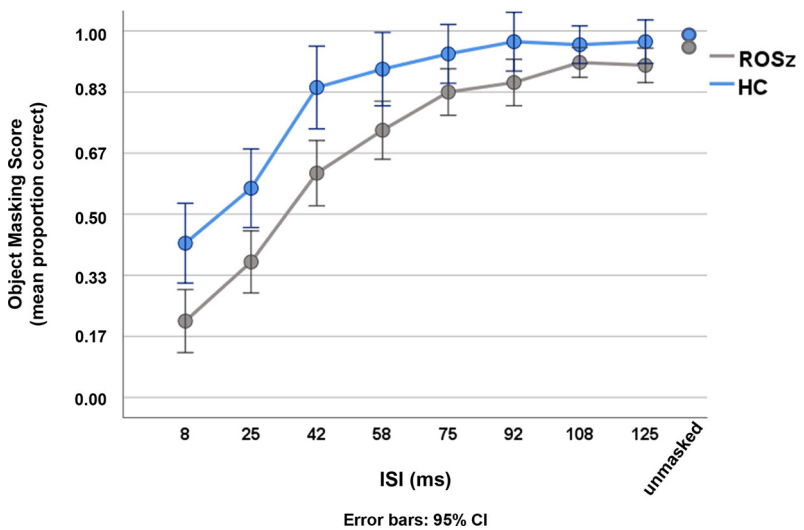

FIGURE 2 | Object Masking performance in recent-onset schizophrenia and healthy controls.

TABLE 2 | Descriptive statistics for visual processing and social cognitive task performance.

	ROSz mean (*s.d.*)	HC mean (*s.d.*)	Contrast *F* or *t* (*df*), *p*-value
Object Masking ISI			
Unmasked	0.95 (0.09)	0.98 (0.06)	Group: t (50) = −1.58, p = 0.12, Cohen's d = 0.47
8 ms	0.21 (0.21)	0.42 (0.29)	
25 ms	0.37 (0.21)	0.57 (0.28)	
42 ms	0.61 (0.28)	0.85 (0.19)	
58 ms	0.72 (0.26)	0.90 (0.15)	
75 ms	0.83 (0.22)	0.94 (0.09)	
92 ms	0.86 (0.22)	0.97 (0.08)	
108 ms	0.91 (0.14)	0.96 (0.06)	
125 ms	0.91 (0.16)	0.97 (0.05)	
			Main effect of ISI: F (3.19, 159.35) = 44.08, p < 0.001, partial η^2 = 0.47
			Main effect of group: F (1,50) = 5.76, p = 0.02, partial η^2 = 0.10
			ISI x group: F (3.19, 159.35) = 8.51, p < 0.001, partial η^2 = 0.15
EmoBio	0.78 (0.08)	0.86 (0.05)	Group: t (50) = −3.66, p = p=0.001, Cohen's d = 1.10
TASIT Lies	0.79 (0.10)	0.88 (0.07)	
TASIT Sarcasm	0.70 (0.14)	0.88 (0.08)	
			Main effect of condition: F (1, 50) = 4.94, p = 0.03, partial η^2 = 0.09
			Main effect of group: F (1, 50) = 38.37, p < 0.001, partial η^2 = 0.43
			Condition x group: F (1, 50) = 4.30, p = 0.04, partial η^2 = 0.08

performance in the patient group steadily improved through 75 ms ISI [p's < 0.001, Cohen's d's ≥ 0.75], before leveling off between 75 and 92 ms ISI [t (31) = 1.57, p = 0.13, Cohen's d = 0.28] reflecting escape from the masking effect.[1]

Social Cognition

Results for the social cognitive tasks are presented in **Figure 3** and **Table 2**. Scores were normally distributed and free of outliers. For the EmoBio task, the ROSz group were less accurate compared to HC [t (50) = 3.36, p = 0.001, Cohen's d = 1.10]. Similarly, for the TASIT, the ROSz group exhibited overall poorer performance compared to HC [F (1,50) = 38.37, p < 0.001, partial η^2 = 0.43]. There was a significant interaction between TASIT condition and group [F (1,50) = 4.30, p = 0.04, partial η^2 = 0.08]. Compared to HC, ROSz exhibited impaired performance on lie [t (50) = −3.54, p = 0.001, Cohen's d = −1.00] and sarcasm [t (50) = −5.17, p < 0.001, Cohen's d = −1.46] detection. However, the ROSz group were disproportionately impaired on items assessing sarcasm detection [t (30) = 3.09, p = 0.004, Cohen's d = 0.55] compared to HC [t (19) = 0.13, p = 0.90, Cohen's d = 0.03].

Relationship Between Visual Processing and Social Cognition

A scatterplot of the relationship between Object Masking performance and social cognitive task performance in the patient sample is displayed in **Figure 4**. Scores for mean Object Masking performance averaged across ISIs were normally distributed and free of outliers. In ROSz, better Object Masking performance was associated with better social cognitive task performance. This was true for both low- and high-level tasks, and the correlations were of similar magnitude (r_{EmoBio}= 0.45, p = 0.01; r_{TASIT} = 0.41, p = 0.02).

Regression analyses were conducted to test whether the relationship between visual processing and higher-level social cognition (i.e., TASIT part 3 performance) was mediated by lower-level social cognition (i.e., Emo Bio). The data were free of multivariate outliers. Object Masking performance was a significant predictor of the proposed mediator [Emo Bio, β = 0.45, t (29) = 2.70, p < 0.001] and the outcome variable [TASIT, β = 0.41, t (29) = 2.41, p = 0.02]. However, Emo Bio performance was not a significant predictor of TASIT performance [β = 0.28, t (29) = 1.58, p = 0.13]. Thus, these data do not provide significant support for mediation.[2]

DISCUSSION

In this study, we evaluated early visual processing, assessed with visual backward masking, and social cognitive task performance in people with recent-onset schizophrenia (ROSz) and healthy controls (HC). We hypothesized that visual backward masking performance and social cognitive task performance would be significantly impaired in ROSz compared to HC. In addition, we hypothesized that visual backward masking performance would be significantly correlated with social cognitive task performance in the ROSz group. Our first hypothesis was supported. Congruent with the findings of Favrod et al. (25) and Perez et al. (22), early visual processing was significantly impaired in the early phase of

[1] Note: Results from a follow-up repeated measures analyses in the ROSz sample that included CPZ equivalents as a covariate did not differ substantively from those reported in the manuscript (main effect of ISI, p < 0.001; main effect of CPZ, p = 0.11, ISI x CPZ, p = 0.68).

[2] Note: Subsequent analyses that included CPZ equivalents did not substantively differ from the results reported above. Specifically, the association between OM and the two social cognition measures remained statistically significant after controlling for CPZ equivalents.

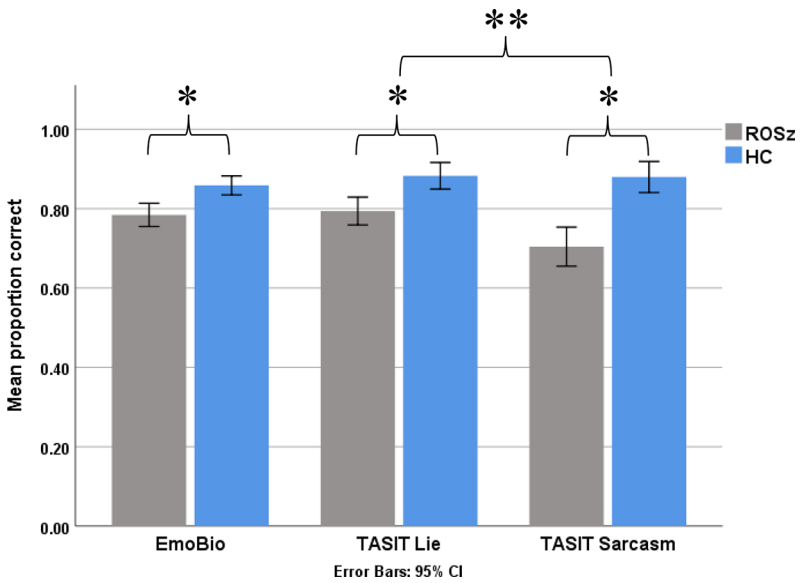

FIGURE 3 | Social cognitive task performance in recent-onset schizophrenia and healthy controls. *Denotes group contrast $p < 0.05$. **Denotes group × condition interaction effect $p < 0.05$.

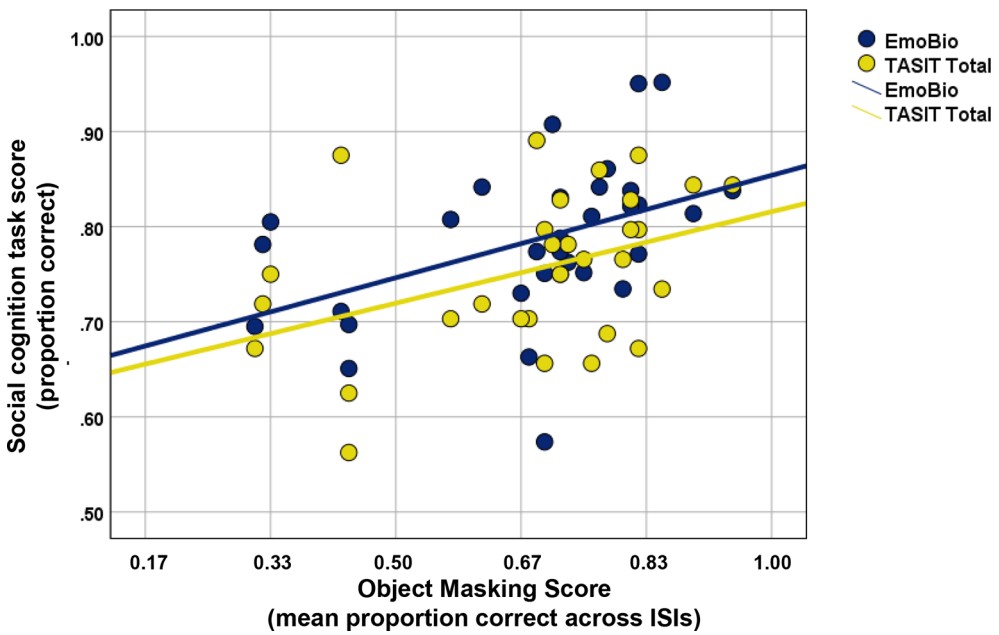

FIGURE 4 | Scatterplot of Object Masking performance and social cognitive task performance in recent-onset schizophrenia.

schizophrenia. The masking effect was exaggerated in the ROSz group. Compared to HC, the ROSz group showed greater interference from the mask, as indicated by lower performance accuracy across ISIs, and the patient group required longer ISIs to escape the masking effect. Similarly, we found support for our second hypothesis: social cognition was significantly impaired in ROSz. The ROSz group exhibited an impaired ability to identify emotional states from body movement cues (low-level social cognition), and impaired theory of mind (high-level social cognition).

An association between visual processing and social cognition has previously been demonstrated in chronic phase schizophrenia (7–14). This relationship is hypothesized to reflect a cascading effect of disruptions of early stages of information processing on downstream cognitive functions (7, 12, 44). Consistent with a cascade model, early visual processing was associated with performance on the social cognitive tasks in this ROSz sample. Thus, our third hypothesis was supported. Consistent with prior findings in chronic schizophrenia (7, 9–14), the strength of the association between visual processing and social cognition was moderate in magnitude. Moreover, the relationship was consistent across low- and high-level social cognition processes.

Although the data supported a cascading effect between visual processing and social cognition, a cascading effect *within* social cognition, i.e., with low-level social cognition performance predicting high-level social cognition, was not supported by the regression analyses. Our results are in contrast to theoretical accounts and empirical data for a hierarchical stream within social information processing (45, 46). However, a major limitation of the current study was the small sample size, which likely rendered the analyses underpowered to detect mediation.

Remediation of the perceptual and cognitive impairments associated with schizophrenia using a neuroplasticity-based, bottom-up training approach is a growing area of research, and the visual system is amenable to training. The studies conducted so far suggest that targeted visual training holds promise for remediating visual processing impairments in people with schizophrenia. Improved performance on trained visual tasks, including visual backward masking, motion perception, contrast sensitivity, visual search efficiency, visual acuity, and perceptual organization have been reported (47–51). Beyond improvements on trained tasks, data from the present study suggest that interventions directed at improving early visual processing might also yield effects on downstream social cognitive processes in those with a recent onset of schizophrenia. This is a question for future research.

CONCLUSIONS

Early-stage visual processing, low-level, and high-level social cognition were all significantly impaired in ROSz. These data provide support for a cascade model of information processing between early-stage visual processing and social cognition in ROSz, but did not support significant cascading effects within social cognition.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by UCLA Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AM, MG, JW, and KN contributed conception and design of the study. AM managed data collection, organized the database, performed the statistical analysis, and wrote the first draft of the manuscript. JW, JL, ER, and MG wrote sections of the manuscript. JV and KS managed subject recruitment, and clinical and cognitive characterization of the sample. All authors contributed to the article and approved the submitted version.

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.