Evidence of aberrant cortical activation during ambiguous object recognition in psychosis

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Background

- Prominent neural models of schizophrenia (SCZ) suggest aberrant connections between brain regions are responsible for observed symptomatology[1]
- Activation of the primary visual cortex (V1) is dependent on complex interactions of feedforward, feedback and horizontal connections[2]
- Aberrant connections to and from V1 may be related to known visual abnormalities in schizophrenia[3]

Objectives

- Identify brain regions that modulate based on recognizability of ambiguous objects while controlling for low level stimulus characteristics
- Investigate whether known dysfunctional visual processing in psychosis is related to feedback connections to primary visual cortex
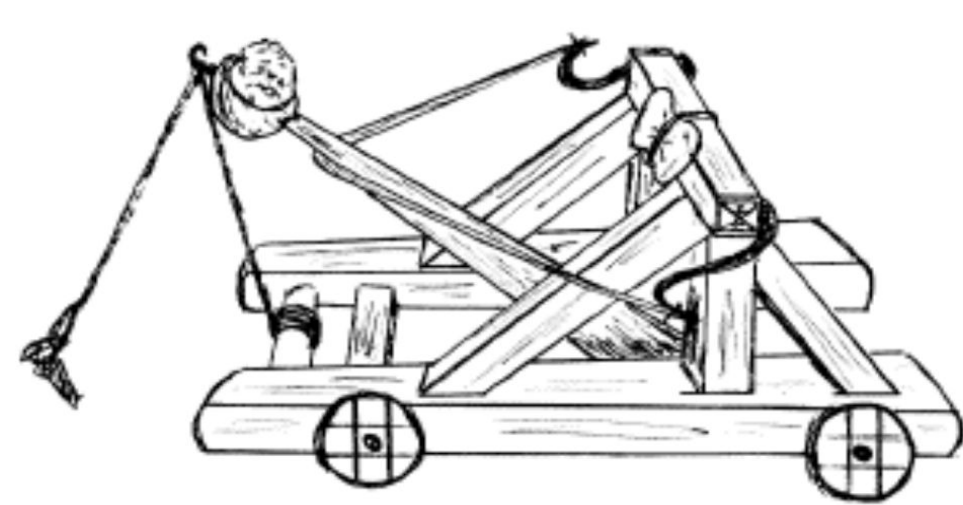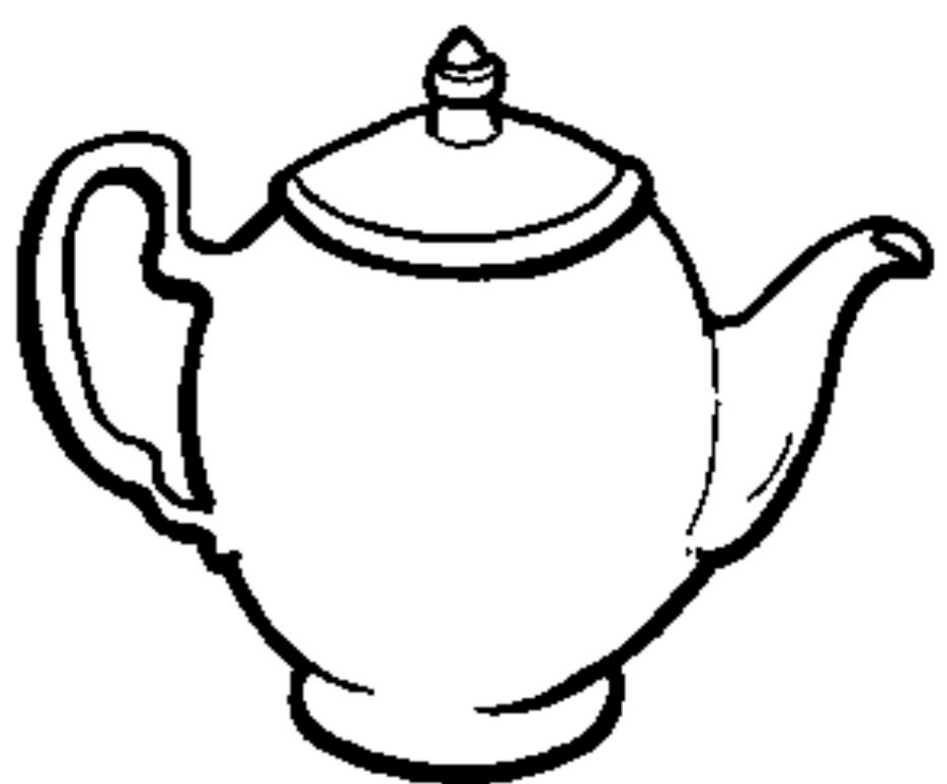
Demographics

Table 1. Participant Demographic Characteristics and Symptom Ratings

Index	SCZ (n=27)	BP (n=22)	CON (n=23)	SREL (n=19)	Statistics	Post Hoc Contrasts
Age	44.9 (10.3)	45.8 (11.2)	47.4 (9.5)	46.8 (9.6)	$F_{(3,87)}$ =.29, p=.834	
Percent Female	19%	50%	48%	74%	$X2(3)$ =14.26, p =.003	SCZ<REL
Education	13.7 (2.1)	15.1 (2.7)	15.9 (1.2)	14.8 (2.0)	$F_{(3,87)}$ =5.21, p=.002	SCZ<CON
Estimated IQ (from WAIS-III)	100.1 (14.1)	103.5 (14.1)	113.5 (12.6)	109.3 (17.9)	$F_{(3,87)}$ =3.96, p=.011	SCZ<CON
Visual Acuity (LogMAR)	.13 (.15)	.12 (.13)	.07 (.13)	.12 (.12)	$F_{(3,87)}$ =.92, p=.434	
Overall Symptomatology (BPRS Total)	39.3 (9.0)	36.7 (8.9)	25.7 (2.0)	30.9 (8.2)	$F_{(3,87)}$ =15.17, p<.001	CON<SCZ,BP,SREL SREL<SCZ, BP
Schizotypal Characteristics (SPQ Total)	36.6 (16.5)	24.4 (15.5)	7.4 (6.3)	18.4 (13.2)	$F_{(3,84)}$ =18.7, p<.001	CON<SCZ,BP,SREL SREL,BP<SCZ
Perceptual Gating (SGI Total)	73.9 (35.3)	73.1 (41.8)	26.9 (17.8)	61.2 (38.7)	$F_{(3,84)}$ =9.21, p<.001	CON<SCZ,BP,SREL

All data are presented as Mean (Standard Deviation), unless otherwise noted. SCZ = patients with schizophrenia , BP = patients with bipolar disorder, SREL = first degree relatives of SCZ, CON = healthy controls. WAIS-III = Wechsler Adult Intelligence Scale, 3rd edition. BPRS = 24-item brief psychiatric Rating Scale. SPQ = Schizotypal Personality Questionnaire. SGI = Sensory Gating Inventory. SGI Total data were not obtained for two SCZ and one CON. SPQ Total data were not obtained for one SCZ, one CON and one SREL. Alpha for all post hoc contrasts was set at .05 and p-values were FDR corrected for multiple comparisons when appropriate.
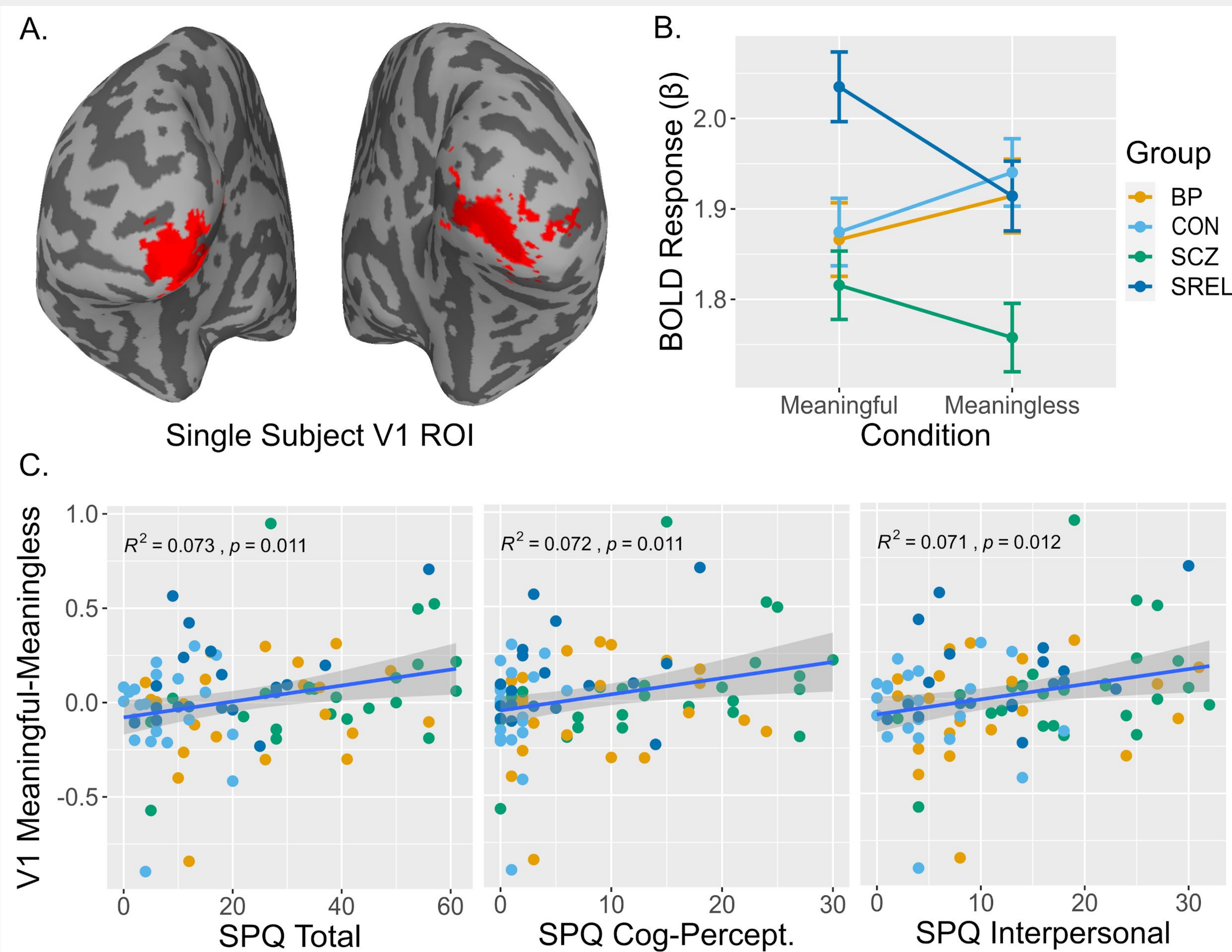
Task

- Participants rated images as "short and fat" (right button press) or "tall and skinny" (left button press) while we collected 3T fMRI data.
- Stimuli were matched for number of line segments and mean orientation of line segments, and categorized as meaningful or meaningless based on ratings made by participants in a separate task

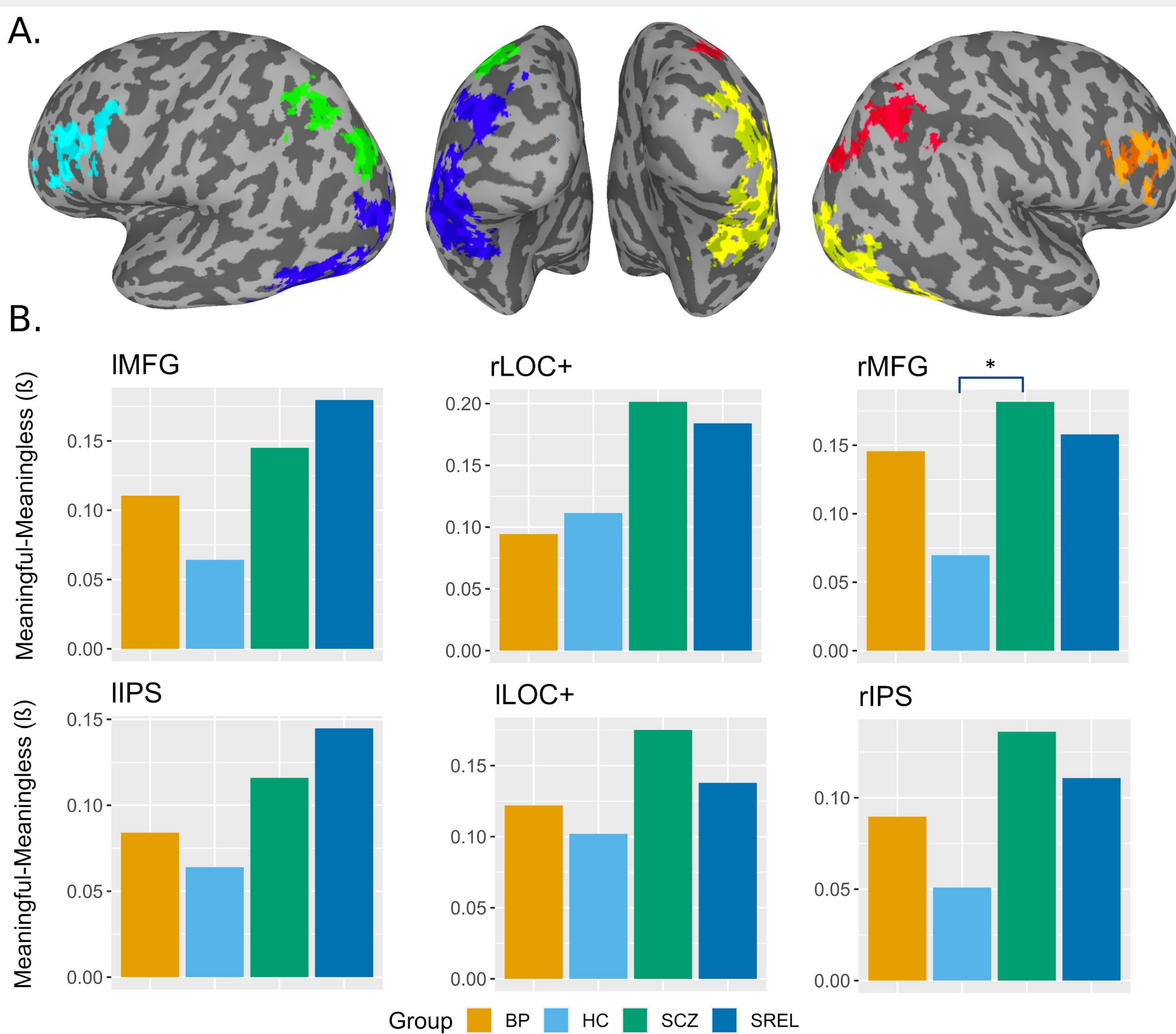Meaningful   Meaningless

Meaningful   Meaningless

Results

A. Single Subject V1 ROI

B. BOLD Response (β) — Meaningful / Meaningless Condition — Group: BP, CON, SCZ, SREL

C. V1 Meaningful-Meaningless vs SPQ Total ($R^2 = 0.073$, $p = 0.011$); SPQ Cog-Percept. ($R^2 = 0.072$, $p = 0.011$); SPQ Interpersonal ($R^2 = 0.071$, $p = 0.012$)

[Panel A] Example V1 ROI for a single subject

[Panel B] Categorical analysis revealed a trending interaction of group and condition (p=.06)

[Panel C] SPQ total and subfactor scores correlated with meaningful-meaningl ess BOLD activation difference scores

A. 6 ROIs

B. lMFG, rLOC+, rMFG, lIPS, lLOC+, rIPS — Meaningful-Meaningless (β) — Group: BP, HC, SCZ, SREL

[Panel A] 6 ROIs were identified by contrasting meaningful-meaning less: lateral occipital cortex/ventral visual areas (left LOC+ = blue; right LOC+ = yellow), middle frontal gyrus (left MFG = teal; right MFG = orange), intraparietal sulcus (left IPS = green; right IPS = red)

[Panel B] SCZ generally exhibited the largest modulation between conditions (i.e. meaningful-meaningl ess difference score), but only significantly differed from HC at rMFG (FDR corrected p = .002)

Conclusions

- Results provide evidence of inefficient processing of meaningful images in participants with higher schizotypal personality trait ratings.
- Stimuli were matched for a variety of low level characteristics suggesting that aberrant feedback processes are primarily responsible for observed V1 effects
- Results also suggest specific deficits in SCZ, as compared to BP and SREL, in high-level cortical regions (e.g. rMFG) during ambiguous object detection.

Acknowledgements

Citations

1. Lanillos, Pablo, Daniel Oliva, Anja Philippsen, Yuichi Yamashita, Yukie Nagai, and Gordon Cheng. 2020. "A Review on Neural Network Models of Schizophrenia and Autism Spectrum Disorder." *Neural Networks: The Official Journal of the International Neural Network Society* 122 (February): 338–63.
2. Lamme, V. A., H. Supèr, and H. Spekreijse. 1998. "Feedforward, Horizontal, and Feedback Processing in the Visual Cortex." *Current Opinion in Neurobiology* 8 (4): 529–35.
3. Butler, Pamela D., Steven M. Silverstein, and Steven C. Dakin. 2008. "Visual Perception and Its Impairment in Schizophrenia." *Biological Psychiatry* 64 (1): 40–47.