pRF Amplitude Differs within the Ventral Visual Processing Stream in Autism

Charlotte A. Leferink (charlotte.a.leferink@dartmouth.edu)
Dartmouth College, Hanover NH, 03755
Yeo Bi Choi (yeo.bi.choi.gr@dartmouth.edu)
Dartmouth College, Hanover NH, 03755
Peter A. Angeli (peter.a.angeli@dartmouth.edu)
Dartmouth College, Hanover NH, 03755
Adam Steel (steel@illinois.edu)
University of Illinois Urbana-Champaign, IL, 61820
Caroline E. Robertson (caroline.e.robertson@dartmouth.edu)
Dartmouth College, Hanover NH, 03755

Abstract

Retinotopic activation patterns in visual regions have been shown to differ between autistic and neurotypical individuals (Schwarzkopf et al., 2014), and may contribute to differences in perception and memory that characterize the condition (Robertson and Baron-Cohen, 2017). Recent work has shown that the posterior-anterior transition from perceptual to memory-related areas is marked by an increase in negative amplitude retinotopic responses, which are thought to play a role in to mnemonic processing (Steel et al., 2021; Steel*, Silson*, et al., 2024) and have not been investigated in individuals with autism. Here, we explored the distribution of retinotopic voxels and their amplitudes from perceptual to mnemonic areas along the ventral visual stream using fMRI and voxel-level modeling. We found that the control group had more retinotopic voxels within parahippocampal place area (PPA) and the ventral place memory area (vPMA) than the autism group. Further, while both groups showed a greater proportion of negative amplitude voxels within mnemonic areas relative to PPA, autists had a greater average percentage of negative retinotopic voxels in PPA and in vPMA than the controls. These findings provide evidence for neural processing differences in autistic individuals that extend beyond early visual cortex into memory processing regions.

Keywords: retinotopy; perceptual visual processing; Autism; hippocampus; ventral place-memory area; negative pRFs

Introduction

Retinotopy is a promiscuous neural code in the visual system (Groen et al., 2022), structuring information processing in both visual and mnemonic areas of the brain (Knapen, 2021; Steel et al., 2021, Steel*, Silson*, et al., 2024). In memory areas, this retinotopic code is negative in amplitude (Knapen, 2021) and is thought to scaffold voxel-wise interactions with perceptual systems (Steel*, Angeli* et al., 2024; Steel*, Silson*, et al., 2024).

Prior work in autism has reported different retinotopic features, such as larger population receptive fields (pRFs), in early visual areas of the brain (Schwarzkopf et al., 2014), which might underpin low-level differences in visual processing observed in the condition (Robertson and Baron-Cohen, 2017). To date, the extent to which differences in retinotopic codes also characterize autism in memory processing regions is unknown.

One model system for studying the transformation of perceptual-mnemonic information lies at the anterior edge of high-level visual cortex. Category-selective visual areas typically show strong positive retinotopic responses, while their paired category-selective memory areas – including the "place memory areas" (Steel et al., 2021) show a greater proportion of negative retinotopic responses (Steel*, Silson*, et al., 2024). Here we ask: Are there differences in retinotopic activation patterns ascending the visual hierarchy to the hippocampus along the ventral visual stream in individuals with autism spectrum condition (ASC) compared to neurotypical individuals?

Methods

Participants. 34 adults (*n* = 18 autism; n=16 neurotypical; mean age = 26.3) participated in this study. Participants had normal or corrected-to-normal vision, and were match for age and spatial IQ. All autism participants had an established Autism Spectrum Disorder diagnosis, and a research-reliable administration of the Autism Diagnostic Observation Schedule (ADOS-2), Module 4 (Lord et al., 2000). Written consent was obtained from all participants in accordance with the Declaration of Helsinki and with a protocol approved by the Dartmouth College Institutional Review Board before the study.

Data acquisition. Data was collected at Dartmouth College. *f*MRI data was recorded on a Siemens Prism

3T scanner (Siemens, Erlangen, Germany), using a multi-echo T2*-weighted sequence.

Retinotopy task. Participants performed a color detection task at fixation, indicating by button press when the white fixation dot changed to red. A bar aperture gradually traversed across the screen while revealing fragments of randomly selected scene images.

Regions of Interest. Probabilistic parcels from Steel et al. (2025) were used to extract scene-selective ROIs on the surface for both PPA and for the ventral place-memory area (VPMA). Hippocampal masks were constrained using FreeSurfer's segmentation.

Retinotopy data. Data was fit using voxel-wise pRF modeling as implemented in AFNI (Silson et al., 2015). We considered model fits with $R^2 > 8\%$ to be significant.

Results

We found a consistent pattern across both the ASC and control groups. On average, both the autism and neurotypical groups showed a higher proportion of retinotopic voxels in visual (PPA) as compared with mnemonic areas (HPC and VPMA) (Fig. 1). The control group showed an overall greater proportion of retinotopic voxels across all three areas, PPA: $t(32) = 11.44$, $p < .001$, VPMA: $t(32) = 5.01$, $p < .001$, and in HPC: $t(32) = 2.11$, $p = .04$. On average, both the autism and neurotypical groups showed a higher proportion of negative retinotopic voxels (-pRFs) in mnemonic (HPC and VPMA) as compared with visual areas (PPA) (Fig. 2). However, the autism group showed an increase in -pRFs relative to controls in PPA, $p < .001$; and in vPMA, $p = .001$; but not in HPC, $p = .75$.

Discussion

Consistent with prior work, our results show the proportion of retinotopic voxels decreases along the visual hierarchy from PPA to the hippocampus (Silson et al., 2021). Importantly, this transition is marked by an increase in negative retinotopic voxels, which prior work has associated with mnemonic processing (Steel*, Silson* et al., 2024; Angeli*, Steel* et al., 2024). For individuals with autism, both patterns are present, but are marked by an overall reduction in retinotopic voxel and an overall increase in negative retinotopic voxels. Future work is needed to extend this observation to a larger sample, as well as to understand the potential functional significance of this pattern for perceptual-mnemonic processes in autism.

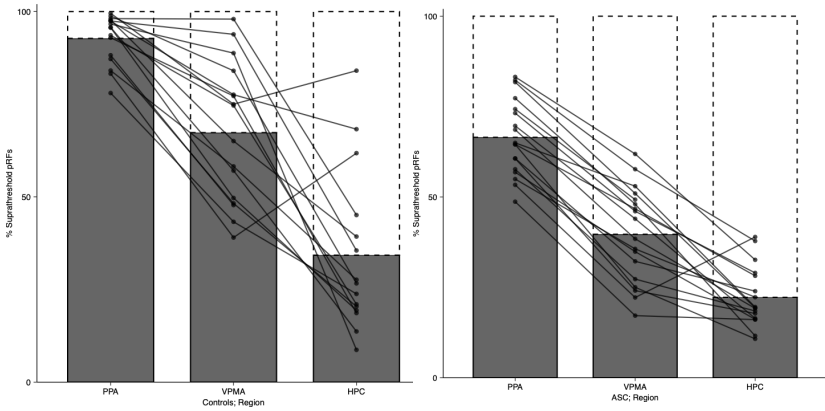

Figure 1. Percentage of significant pRFs across the early visual cortex, the PPA, the VPMA, and the hippocampus, for the control group (left) and the autism group (right).

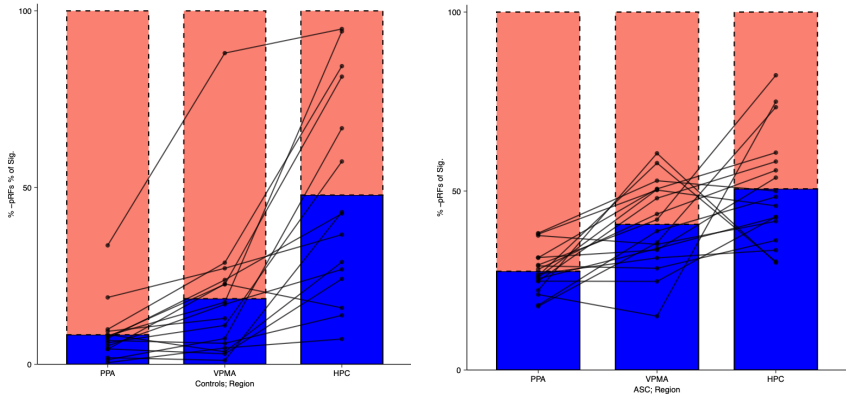

Figure 2. Percentage of negative amplitude pRF voxels across the regions of interest for the control group (left) and the autism group (right).

References

Angeli* P., Steel*, A., Silson, E. & Robertson, R. (2024). Positive and negative retinotopic codes in the human hippocampus. *BioRxiv* [Preprint]. https://doi.org/10.1101/2024.09.27.615397

Groen, I.A., Dekker, T.M., Knapen, T., & Silson E.H. (2022). Visuospatial coding as ubiquitous scaffolding

for human cognition. *Trends in Cognitive Science, 26*(1).

Knapen, T. (2021). Topographic connectivity reveals task-dependent retinotopic processing throughout the human brain. *PNAS, 118*(2).

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr, Leventhal, B. L., DiLavore, P. C., Pickles, A., & Rutter, M. (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, *30*(3), 205–223.

Robertson, C.E., & Baron-Cohen, S. (2017). Sensory perception in autism. *Nature Review Neuroscience*, 18(11):671-684.

Schwarzkopf, D.A., Anderson, E.J., de Haas, B., White, S.J., Rees, G. (2014). Larger extra striate population receptive fields in autism spectrum disorders. *The Journal of Neuroscience*, 34(7):2713-2724.

Silson, E.H., Chan A., W., Reynolds, R.C., Kravitz, D.J., & Baker, C.I. (2015). A retinotopic basis for the division of high-level processing between lateral and ventral human occipitotemporal cortex. *The Journal of Neuroscience, 35*(34):11921:11935.

Silson E.H., Zeidman, P., Knapen, T., & Baker, C.I. (2021). Representation of contralateral visual space in the human hippocampus. *Journal of Neuroscience, 41*(11):2382-2392

Steel A., Billings, M.M., Silson, E.H., Robertson, C.E (2021). A network linking scene perception and spatial memory systems in posterior cerebral cortex. *Nature Communications*, 12:2632. https://doi.org/10.1038/s41467-021-22848-z

Steel*, A., Angeli*, P.A., Silson E.H., Robertson, C.E. (2024). Retinotopic coding organizes the interaction between internally and externally oriented brain networks. *BioRxiv* [Preprint]. https://doi.org/10.11012024.09.25.615084

Steel*, A., Silson*, E.H., Garcia, B.D., Robertson, C.E. (2024). A retinotopic code structures the interaction between perception and memory systems. *Nature Neuroscience, 27*(2): 339-347.

Steel, A., Prasad, D., Garcia, B.D., Robertson, C.E. (2025). Relating scene memory and perception activity to functional properties, networks, and landmarks of posterior cerebral cortex- a probabilistic atlas. *BioRxiv* [Preprint]. https://doi.org/10.1101/2025.01.06.631538