Organization of high-level visual cortex in human infants

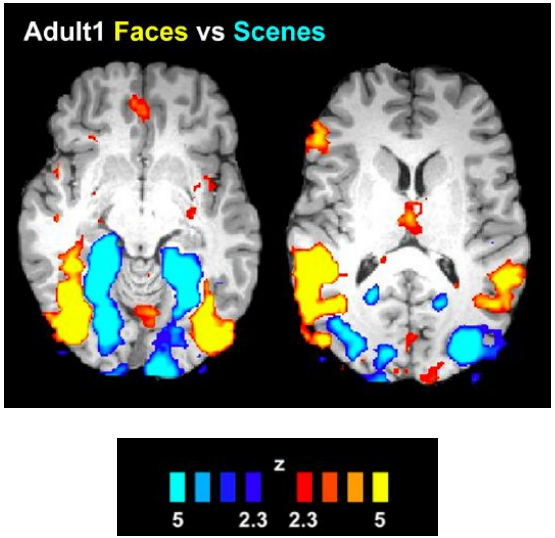
Deen B, Richardson H, Dilks DD, Takahashi A, Keil B, Wald LL, Kanwisher N, Saxe R (2017)

02/13/2021 Lab Presentation

Background

Category-selective regions in extrastriate visual cortex - *2 ways of looking at it*

(1) Stimuli → Activation



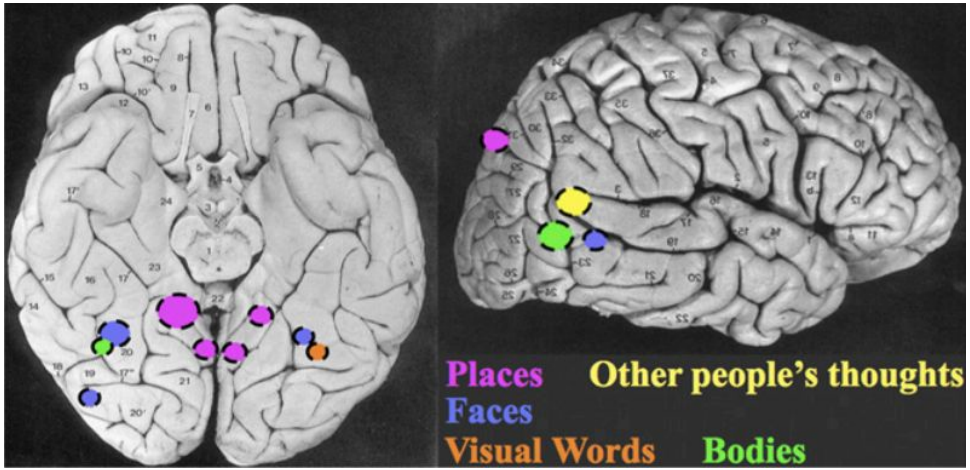
(2) Activation → Perception

		
Fusiform Face Area	*…just for the very first second… I saw an eye, an eye, and a mouth.*	*How do I explain this? Just like the previous one, I see an eye, an eye, and a mouth, sideways.*
Color-preferring site	*The left side of the box looks like a rainbow.*	*If I look at the ball, the rainbow is there, wider than before, and blinking.*

Schalk G et al., (2017)

Background

Category-selective representation in high-level visual cortex - ***Faces, Places, Objects, Bodies, ...***



Kanwisher N (2010)

e.g.
Fusiform Face Area (FFA)
Occipital Face Area (OFA)
Parahippocampal Place Area (PPA)
Occipital Place Area (OPA)

Motivation

Question: is category-selective representation for visual perception early matured during or late developed, and to what extent?

Gaps: Difficulties in acquiring functional neuroimaging data from awake infants

Current Study:

1. Infant-friendly experimental paradigm (headset, stimuli, environment,...)
2. Rigorous statistical measures (discounting motion artifacts, robust inferences,...)

Outline

1. Experimental Paradigms
2. Four main results answering three hierarchical research questions
3. Two main implications

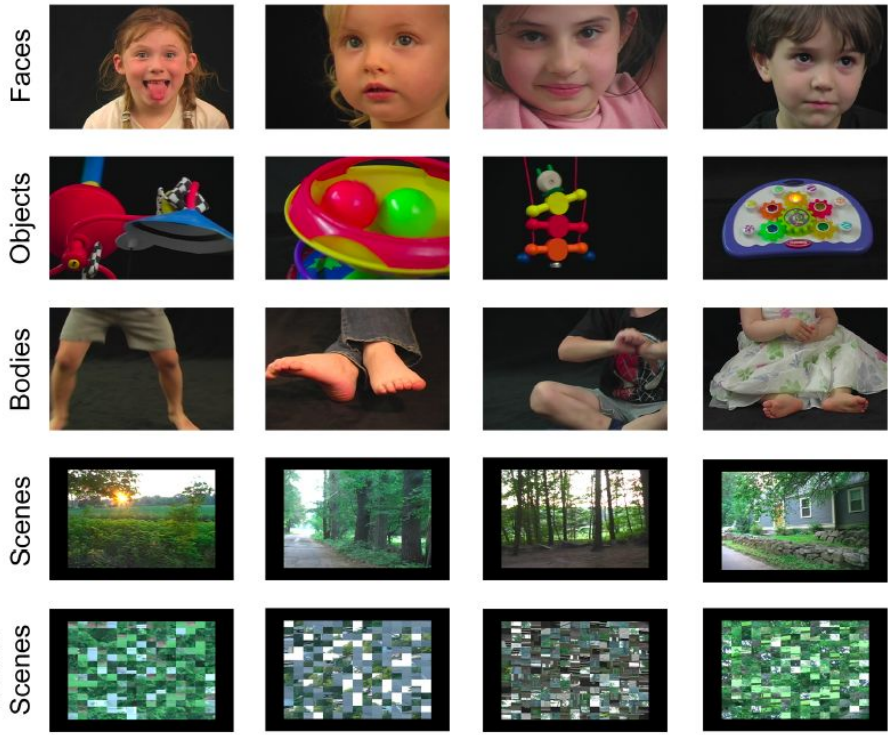
Setups

1. Subjects: 9 infants (3-6 MO)
3 adults (27-34 YO)

3. Measurement: MRI & low motion fMRI data

4. Procedure: Experiment 1, Experiment 2-8

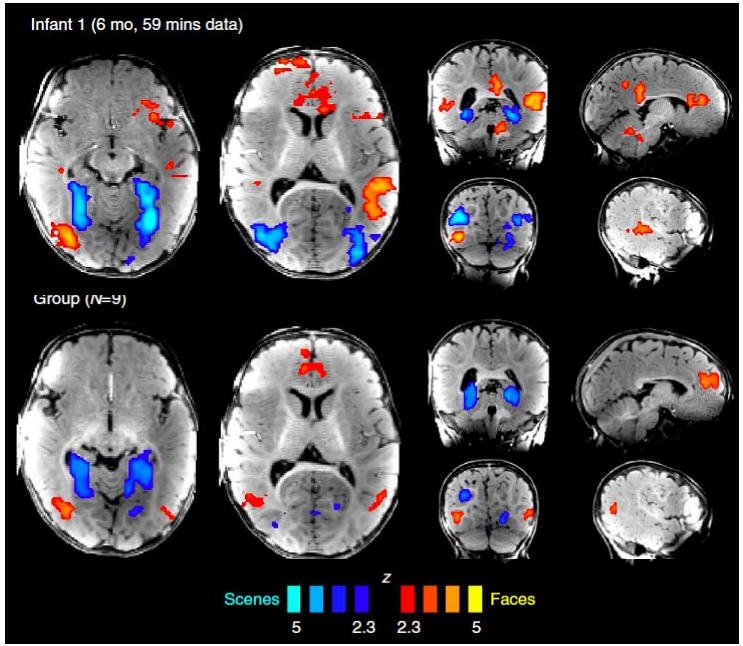
2. Stimuli: Movie Clips

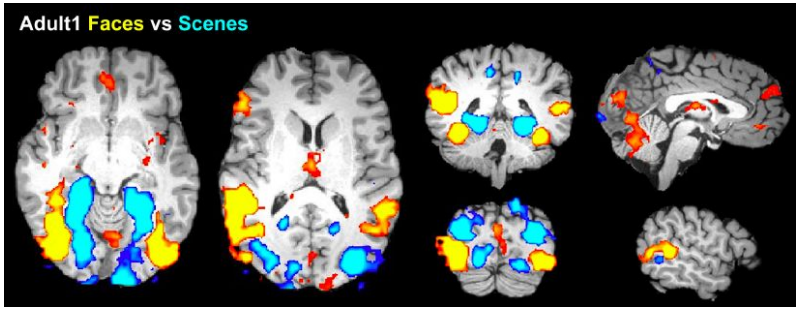


Question #1

Compared with adults, do infants have similar category-sensitive response patterns (face vs scene)?

Whole-brain Results





Voxelwise linear models ($p < .01$; corrected for multiple comparison $p < .05$)

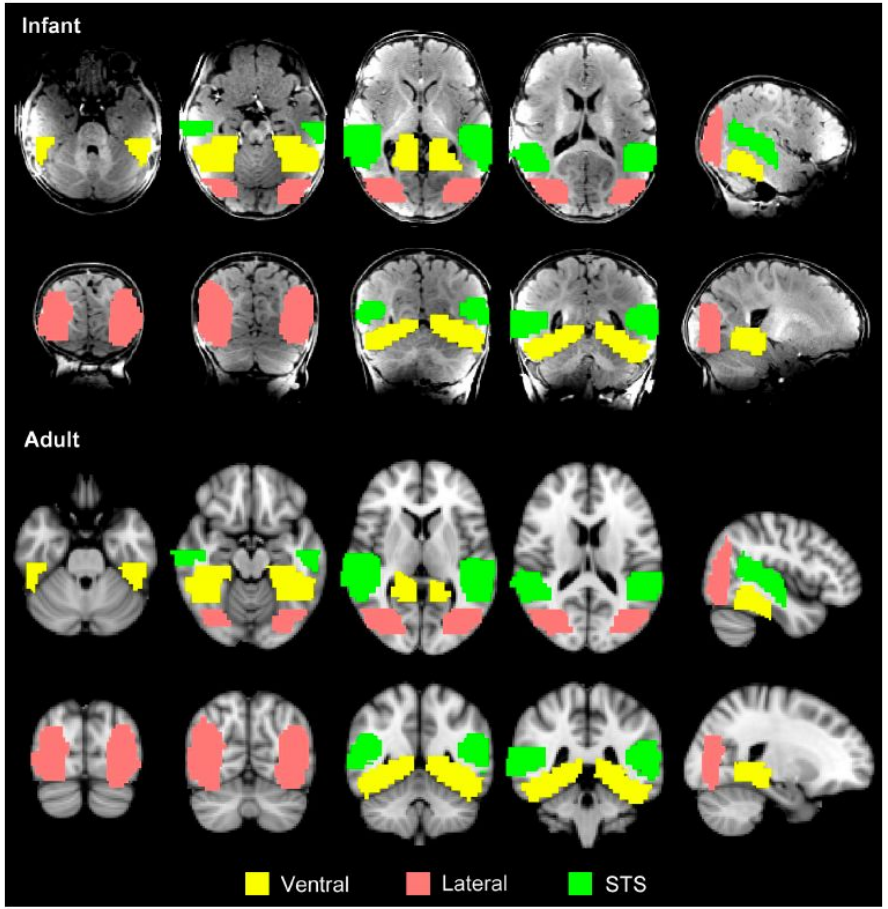
Takeaways: face- and scene-preferring regions were observed in individual infant and infant group.

Anatomical search spaces for ROIs

- Ventral temporal cortex: FFA, PPA
- Lateral occipital cortex: OFA, OPA
- STS face area.

Regions were hand-drawn on the image of one participant, and registered to other participants.

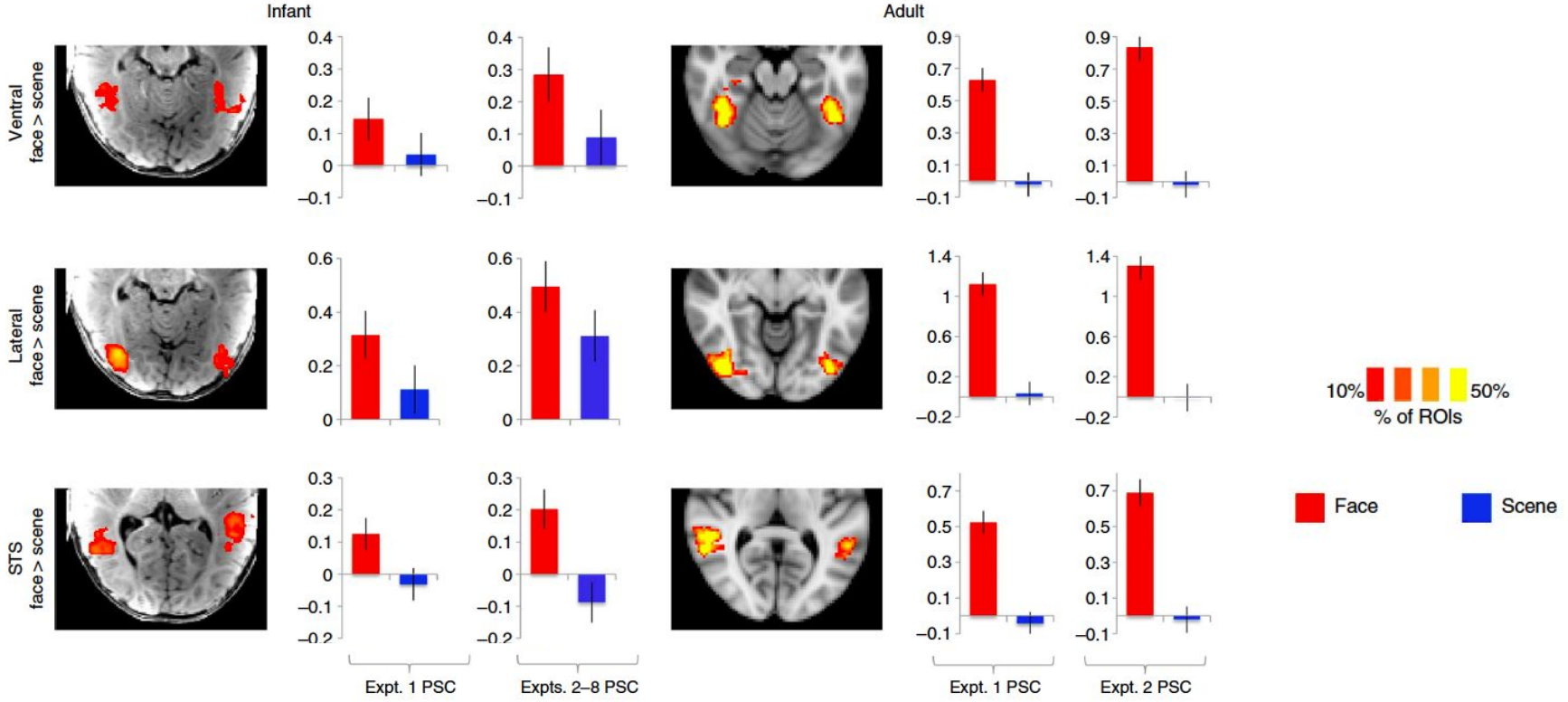
Template



Question #1 (Cont.)

ROI - top 5% of voxels responding to F over S
Heatmap - % ROIs included in a voxel
Bar chart - % signal change; error bar from permutation test

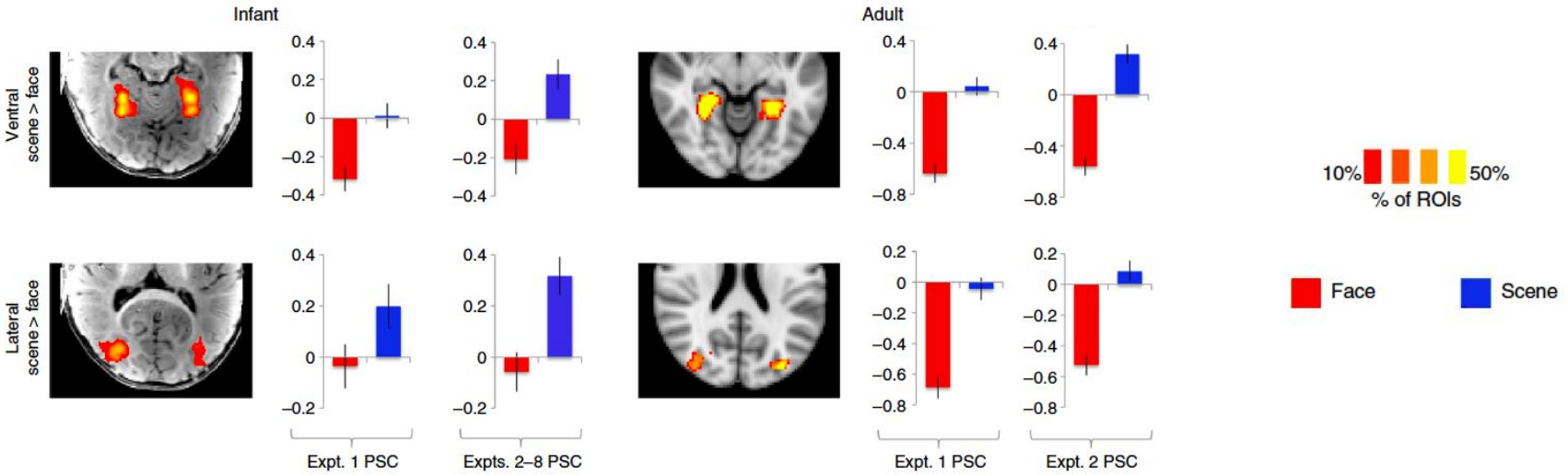
ROI Results



Question #1 (Cont.)

ROI Results

ROI - top 5% of voxels responding to S over F
Heatmap - % ROSs across all participants
Bar chart - % signal change; error bar from permutation test

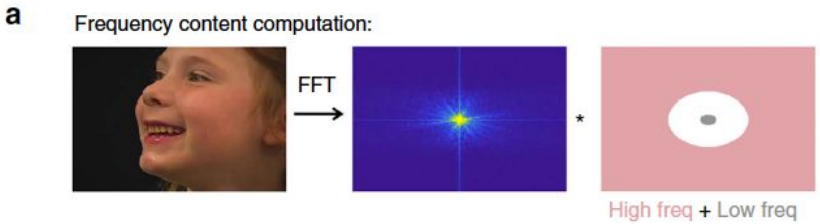


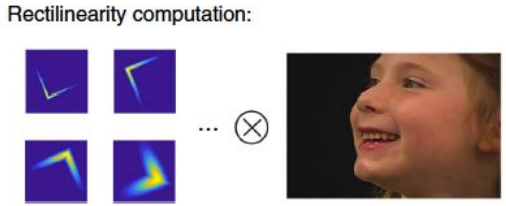
Takeaways: reliable face and scene preferences were observed in ROIs in all regions defined.

Question #2

Can the category-sensitive response of infant be explained by **categories** or **low-level visual features** and **rectilinearity**?

For each stimulus, for each frame, compute the feature values:



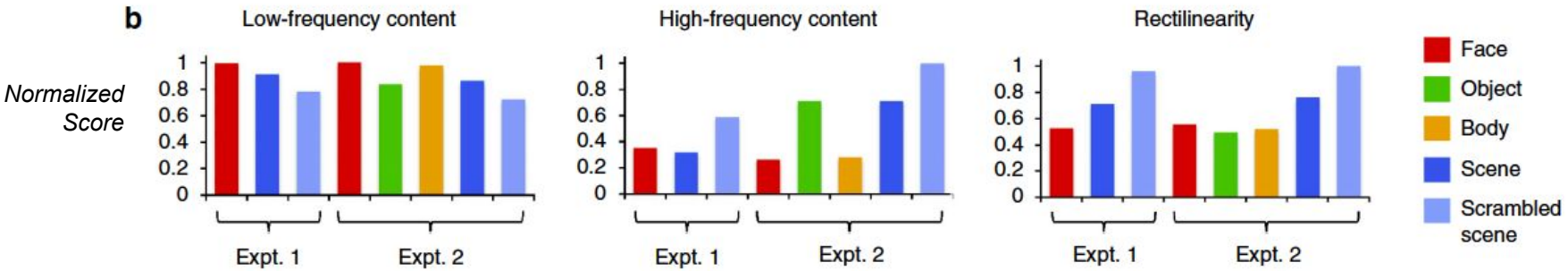


Low: less than 1 cycle per degree of visual angle
High: greater than 5 cycle per degree of visual angle

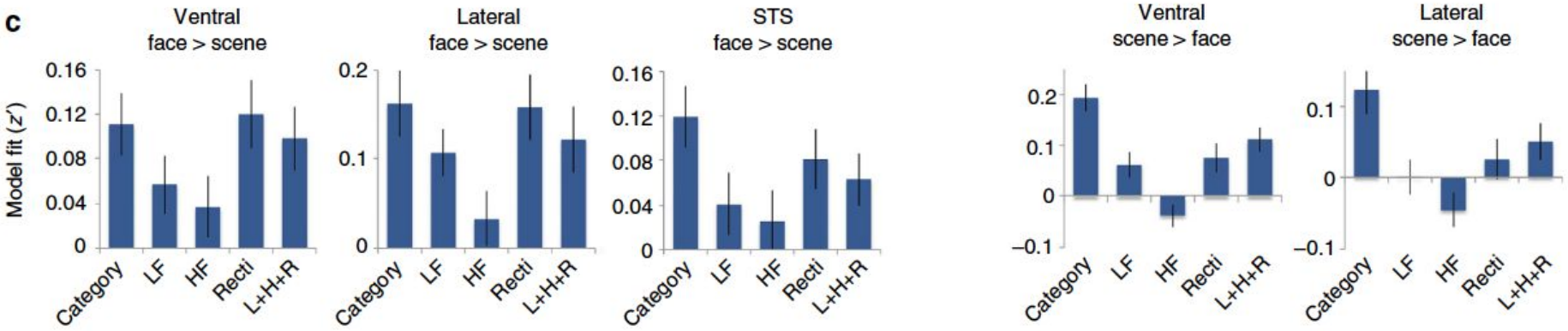
Measure: total power

Nasr et al. (2014)

Question #2 (Cont.)



Question #2 (Cont.)

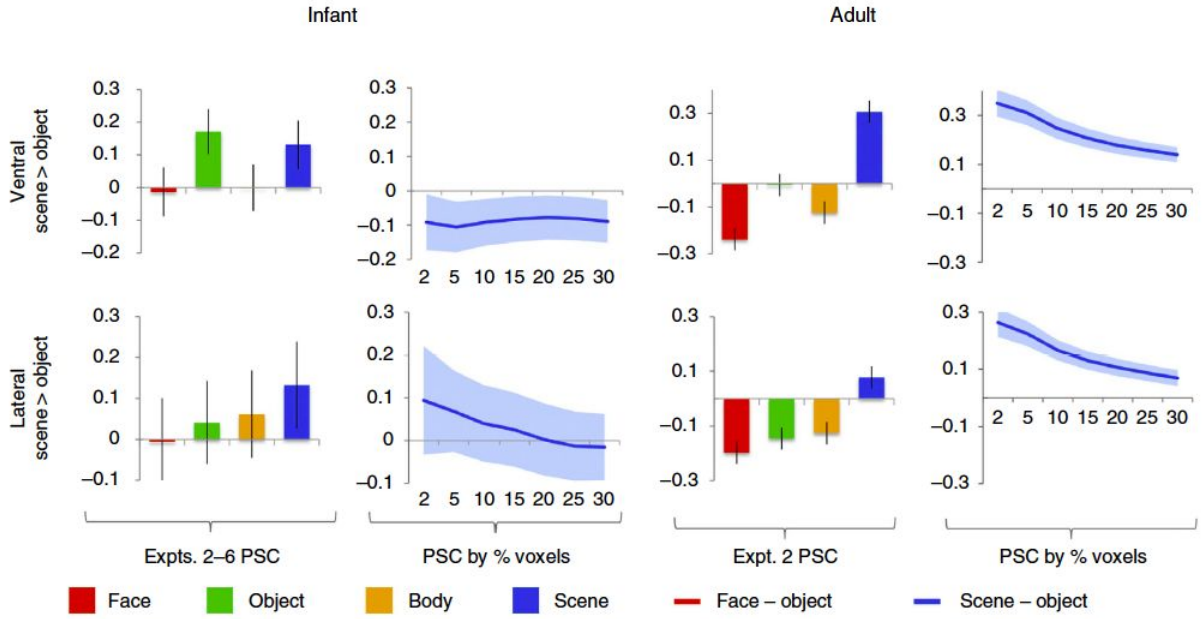


Leave-one-out Cross validation
Z': Fisher Transform Correlation between the left-one and predicted value.

Takeaways: there is no evidence that low-level features drive the category sensitivity better than category itself.

Question #3

Compared with adults, do infants have similar large-scale patterns of response to categories other than faces and scenes?

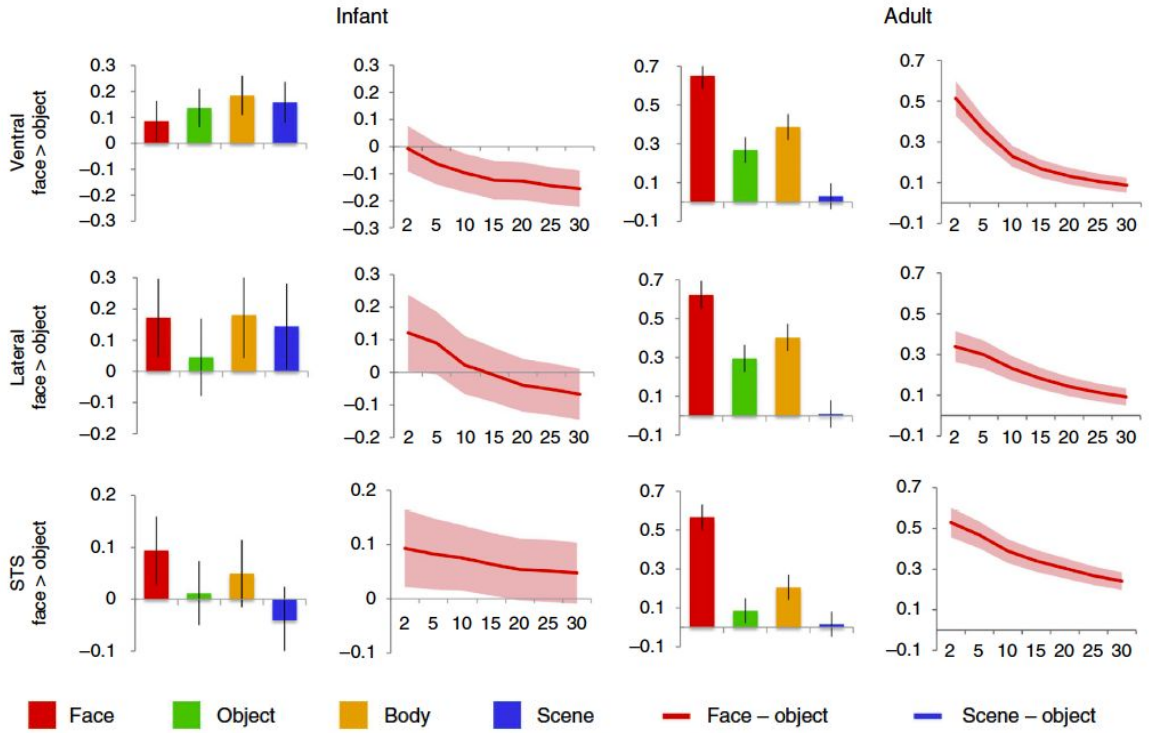


ROI - top 5% of voxels responding to S over O

Bar: percentage of change

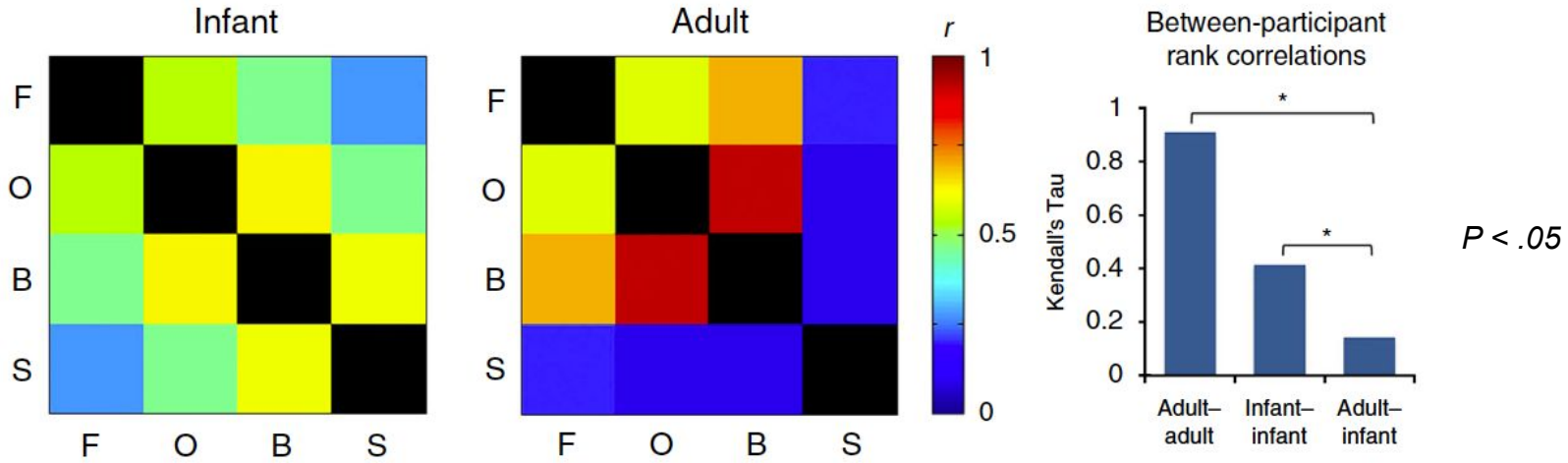
Line: Percentage of by N% ROI voxels

Question #3 (Cont.)



Takeaways: In infants, no region showed a higher response to face or scenes over objects.

Question #3 (Cont.)

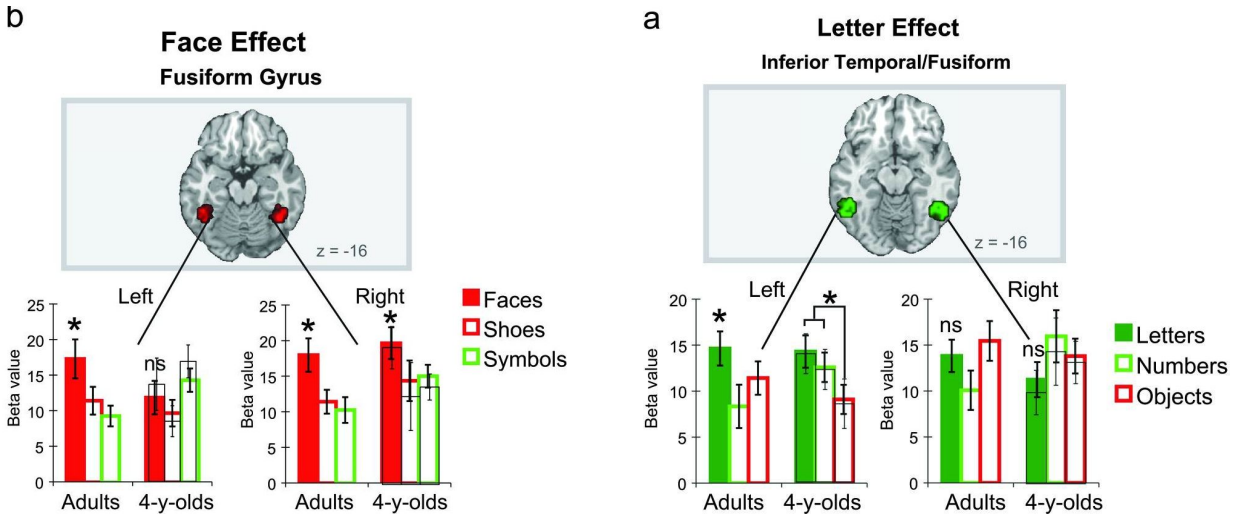


P < .05

Takeaways: even though face and scene responses are dissimilar in both infants and adults, the patterns of similarity across all categories differ.

Implication #1

This study provided a stronger constraint on theories of visual cortical development: high-level category selectivity must either be determined inatly, without any need for visual experience, or develop within the first few months.



Cantlon JF (2011)

Implication #2

The fine-grained selectivity and spatial pattern of activity across multiple categories change with age.

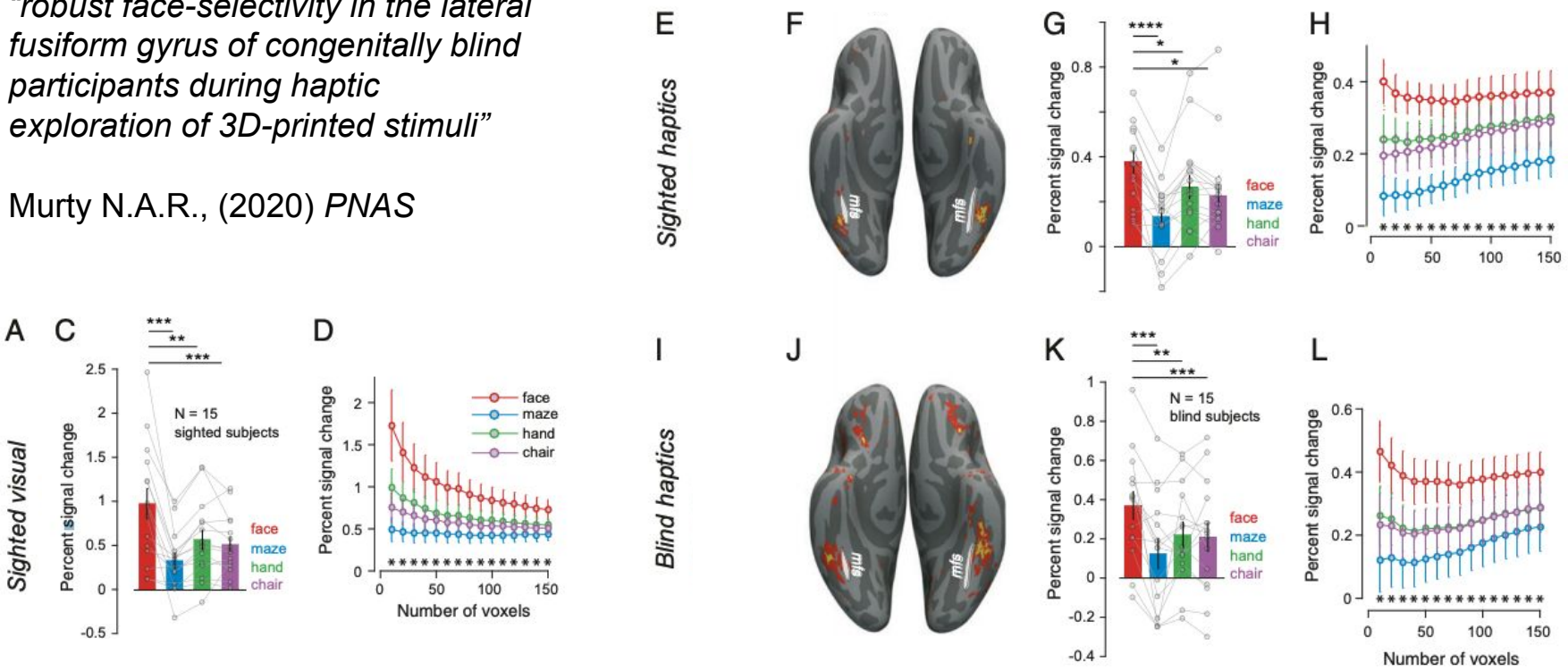
Possibilities:

1. In adults, category-selectivity is enhanced by top-down feedback or attention
2. Physiological maturation, e.g. myelination of long-range connections between brain regions
3. **Visual experience**
4. Extensive trainings with noval symbols

Possibility - visual experience?

“robust face-selectivity in the lateral fusiform gyrus of congenitally blind participants during haptic exploration of 3D-printed stimuli”

Murty N.A.R., (2020) *PNAS*



References

Main:

1. Deen B., Richardson H., Dilks D.D., Takahashi A., Keil B., Wald L.L., Kanwisher N., Saxe R. (2017) **Organization of high-level visual cortex in human infants.** *Nature Communication*, 8:13995.

Supplementary:

1. Kanwisher N. (2010) **Functional specificity in the human brain: A window into the functional architecture of the mind.** *PNAS*, 107(25):11163–11170.
2. Cantlon J.F., Pinel P., Dehaene S., Pelphrey K.A. (2011) **Cortical Representations of Symbols, Objects, and Faces Are Pruned Back during Early Childhood.** *Cerebral Cortex*, 21(1):191–199.
3. Schalk G., Kapeller C., Guger C., Ogawa H., Hiroshima S., Lafer-Sousa R., Saygin Z. M., Kamada K., Kanwisher N. (2017) Facephenes and rainbows: **Causal evidence for functional and anatomical specificity of face and color processing in the human brain.** *PNAS*, 114(46):201713447
4. Murty N.A.R., Teng S., Beeler D., Mynick A., Oliva A. Kanwisher A. (2020) **Visual experience is not necessary for the development of face-selectivity in the lateral fusiform gyrus.** *PNAS*, 117 (37):23011-23020.