# Quantifying the role of perceived curvature in the processing of natural object images

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES
UNIVERSITÄT LEIPZIG
IMPRS on Cognitive Neuroimaging INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

**Laura M. Stoinski[1,2,3], Diego García Cerdas[4], Florian Mahner[3], Parsa Yousefi[3,4], & Martin N. Hebart[4,5,6]**

1 University of Leipzig, Germany; 2 International Max Planck Research School (IMPRS CoNI);
3 Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany; 4 University of Amsterdam, The Netherlands;
5 Justus-Liebig-University, Giessen, Germany; 6 Center for Mind, Brain and Behavior, Universities of Marburg, Giessen and Darmstadt

Center for Mind, Brain and Behavior CMBB
JUSTUS-LIEBIG-UNIVERSITAT GIESSEN
UNIVERSITY OF AMSTERDAM

## Background

- Curvature is suggested as a fundamental organizational dimension of object responses, supporting higher-level categorization [1, 2]
- While there may be a clear definition of curvature for artificial stimuli, defining the global curvature of naturalistic object images remains challenging

global shape vs. local features | how to deal with background features? | how to deal with object cropping, viewing angle, & lighting?

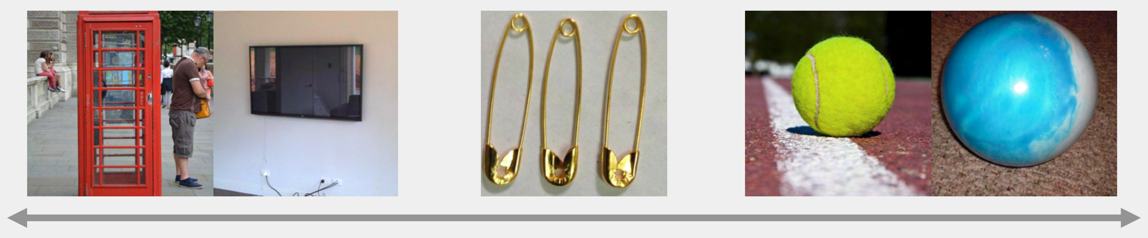
**Can people rate the global curvature of naturalistic object images, and how does this perceived curvature relate to neural object responses?**

**What are the features contributing to people's perception of curvature?**

## Methods

### Perceived curvature ratings

- Rich dataset of curvature ratings for > 27k natural object images of the THINGS database [3, 4]




**Split-half reliability**
r = 0.93

### Computed curvature

- MLV-toolbox [5]
- Li & Bonner [2]

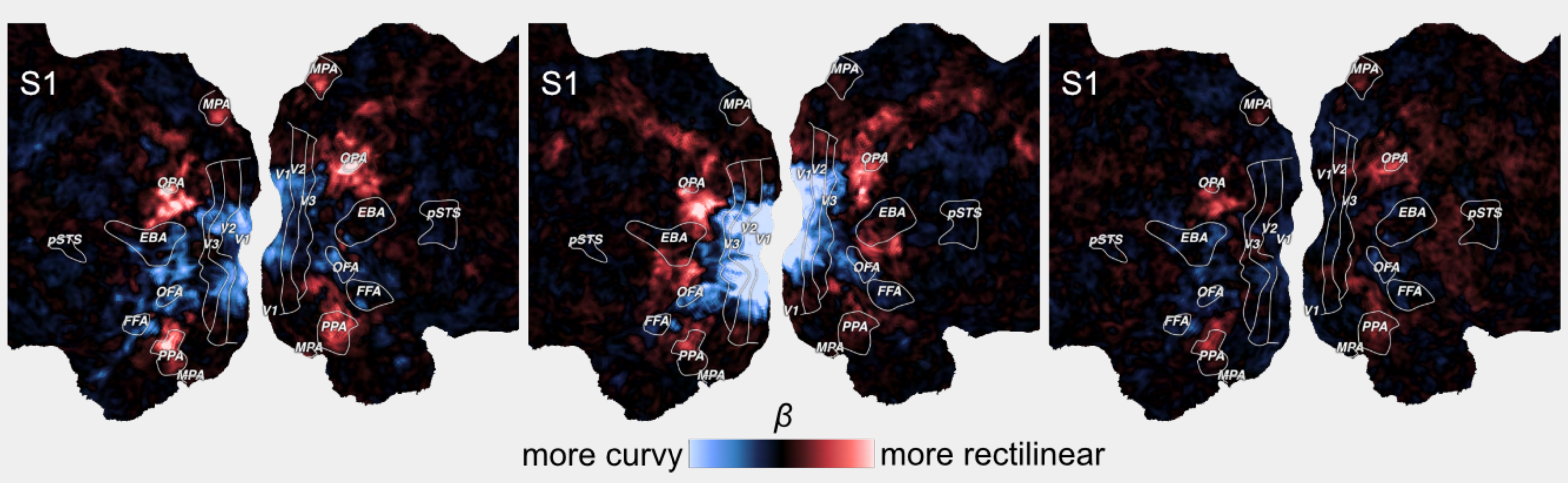
| | perc. | MLV | L&B |
|---|---|---|---|
| perceived | 1.00 | -0.26 | -0.22 |
| MLV | -0.26 | 1.00 | 0.14 |
| Li & Bonner | -0.22 | 0.14 | 1.00 |

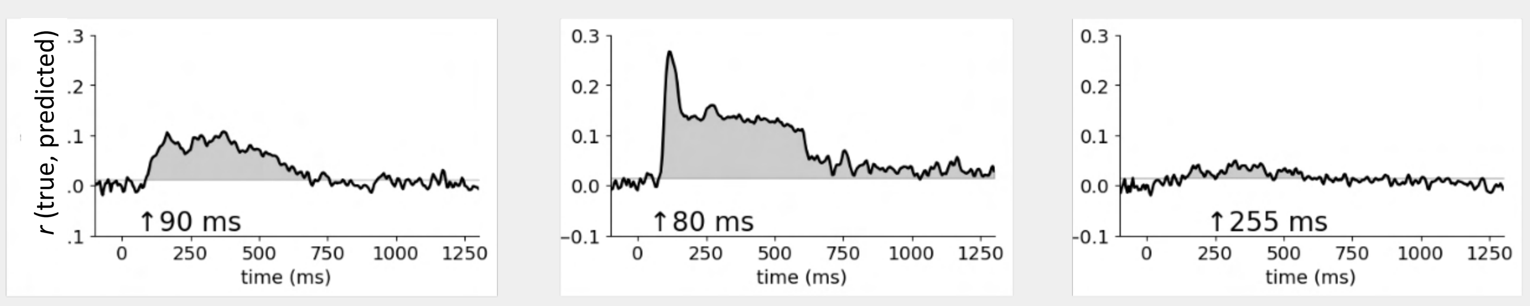
### THINGS-Data [6]

- **fMRI** responses of 3 participants to 8,640 natural images of 720 object concepts
- **MEG** responses of 4 participants to 22,449 natural images of 1,854 object concepts

## How does perceived curvature relate to neural object responses?

**→ Curvature measures relate to distinct brain patterns with perceived curvature best reflecting known category selectivity [1]**

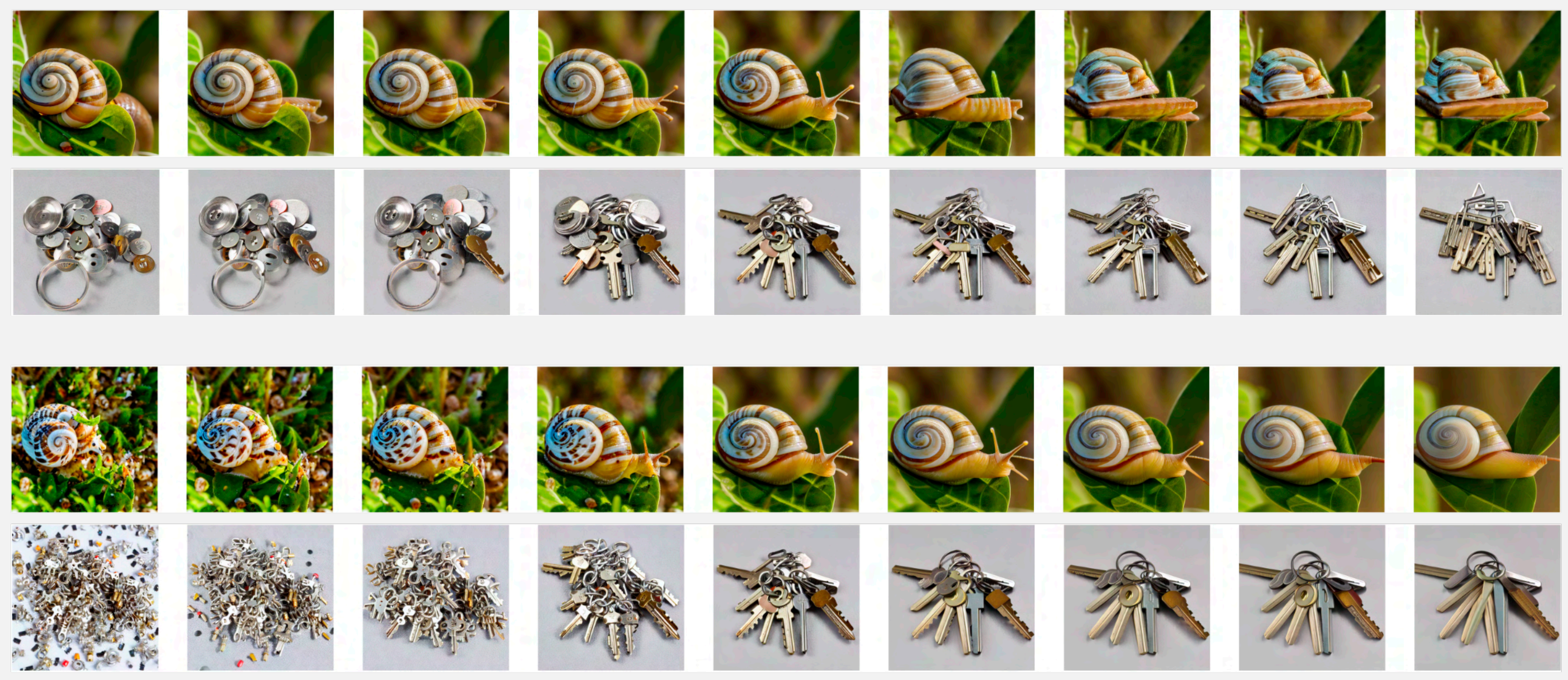



## Which image features underlie curvature measures?

**BrainACTIV** [7]: diffusion-based model, allowing to modify the perceived or computed curvature of object images, whilst preserving most semantic and low-level visual features

**→ People use more global image features to rate perceived curvature vs. MLV-toolbox curvature is based on more local features**

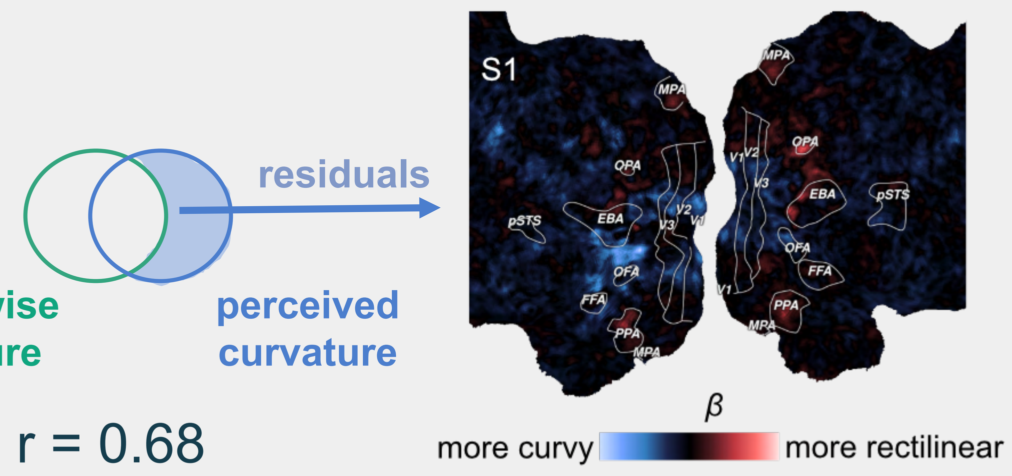



## What is the role of semantics in perceived curvature?

- Object-wise GPT4o-generated curvature captures much of the neural effects of image-wise perceived curvature

**→ Perceived curvature can be partly inferred from semantic object category, suggesting it may pose a bridge between vision and semantics**

**GPT-4**
Text-based, GPT4o-generated curvature scores for 1,854 object categories




r = 0.68

## How can we efficiently quantify the perceived curvature of novel images?

**pCurvComp:** Barlow-Twin-RN50 [8] based model predicting perceived curvature of novel images

**High prediction accuracy**

$R^2 = 0.77$

**High generalizability** [1]

$R^2 = 0.84$ $R^2 = 0.62$

**RISE** [9] **saliency maps**

curvier — more rectilinear

## Conclusion

- Perceived curvature as candidate **organizational dimension** of visual object representations
- **Global image features** as well as **semantics** may contribute to people's perception of curvature

  **→ Curvature as crucial organizational principle bridging vision and semantics**

- Recognizing its importance, we make perceived curvature image-computable with **pCurvComp**

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CCN 2025 laurastoinski.com stoinski@cbs.mpg.de