The Dimensionality Gap: DNNs *vs* Visual Cortex

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Motivation

Studies of the **human brain** often find **low-dimensional** latent signal ...

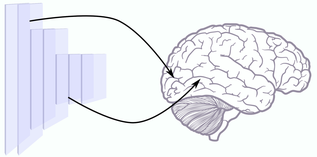
semantic space[1] | visual action representations[2] | human audition[3]

... but recent findings suggest much **higher-dimensional** representations

monkey PFC[4] | mouse vision[5] | human kinematics[6]

1 How many dimensions contain stimulus-related signal?

DNNs are the best models of ***visual cortex***

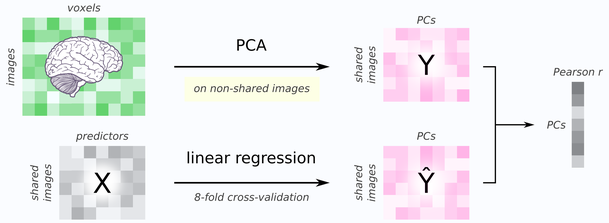


2 Do DNNs explain all the *signal dimensions* in visual cortex?

Methods

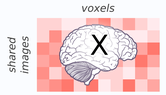
Natural Scenes fMRI Dataset[7]

Approach: To identify candidate dimensions, compute the principal components of the neural responses



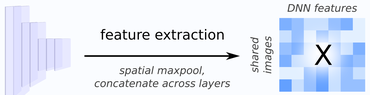
Rationale: If *independent* neural responses can predict a dimension, it suggests that the dimension contains *stimulus-related signal*

1 **Predictors**
neural responses from another participant



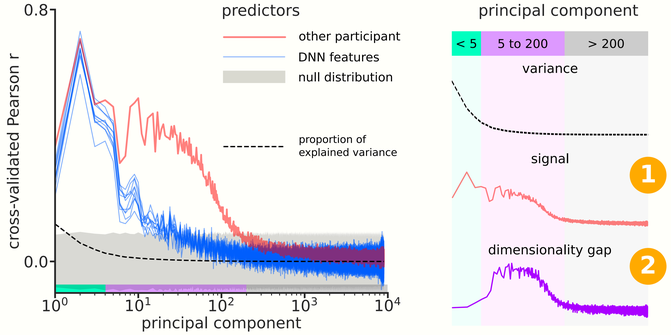
ROIs
V1, V2, V3, V4
place-selective areas (OPA, PPA, RSC)
face-selective areas (OFA, FFA)
body-selective areas (EBA, FBA)
word-selective areas (OWFA, VWFA)

2 **Predictors**
DNN features



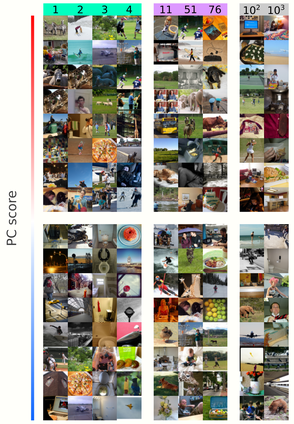
Models
AlexNet
VGGNets (VGG-16, -19)
ResNets (ResNet-18, -50, -50-Barlow-Twins)
Vision Transformers (ViT-B/16, -B/32, -L/16, -L/32)

Results



Visual cortex has *many* low-variance signal dimensions *not* explained by DNN encoding models

Visualizing the dimensions



DNN encoding performance is driven by a few high-variance dimensions

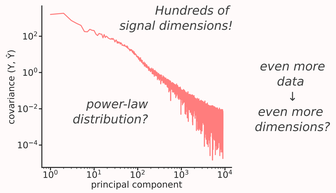
PC 1: 🧍
PC 2: **humans** *vs* **non-humans**
PC 3: **bathrooms** *vs* **non-bathrooms**
PC 4: **animate** *vs* **inanimate**

A novel metric to compare DNNs and the brain

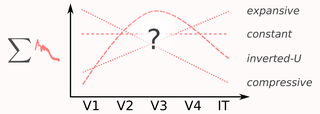
Dimensionality Gap

Future

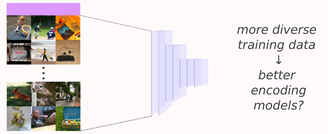
Is signal heavy-tailed?



How does signal dimensionality vary across the brain?



Improving DNN encoding models



References

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Image credits: brain (10.5281/zenodo.3925989); monkey (10.0.20.161/zenodo.4662738); mouse (10.5281/zenodo.3925965); hand (10.5281/zenodo.3926113)

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