WHAT THE SUCCESS OF BRAIN IMAGING IMPLIES ABOUT THE NEURAL CODE

Guest, O., Love, B. C. (2017). What the Success of Brain Imaging Implies about the Neural Code. *eLife*. doi: 10.7554/eLife.21397.

Olivia Guest

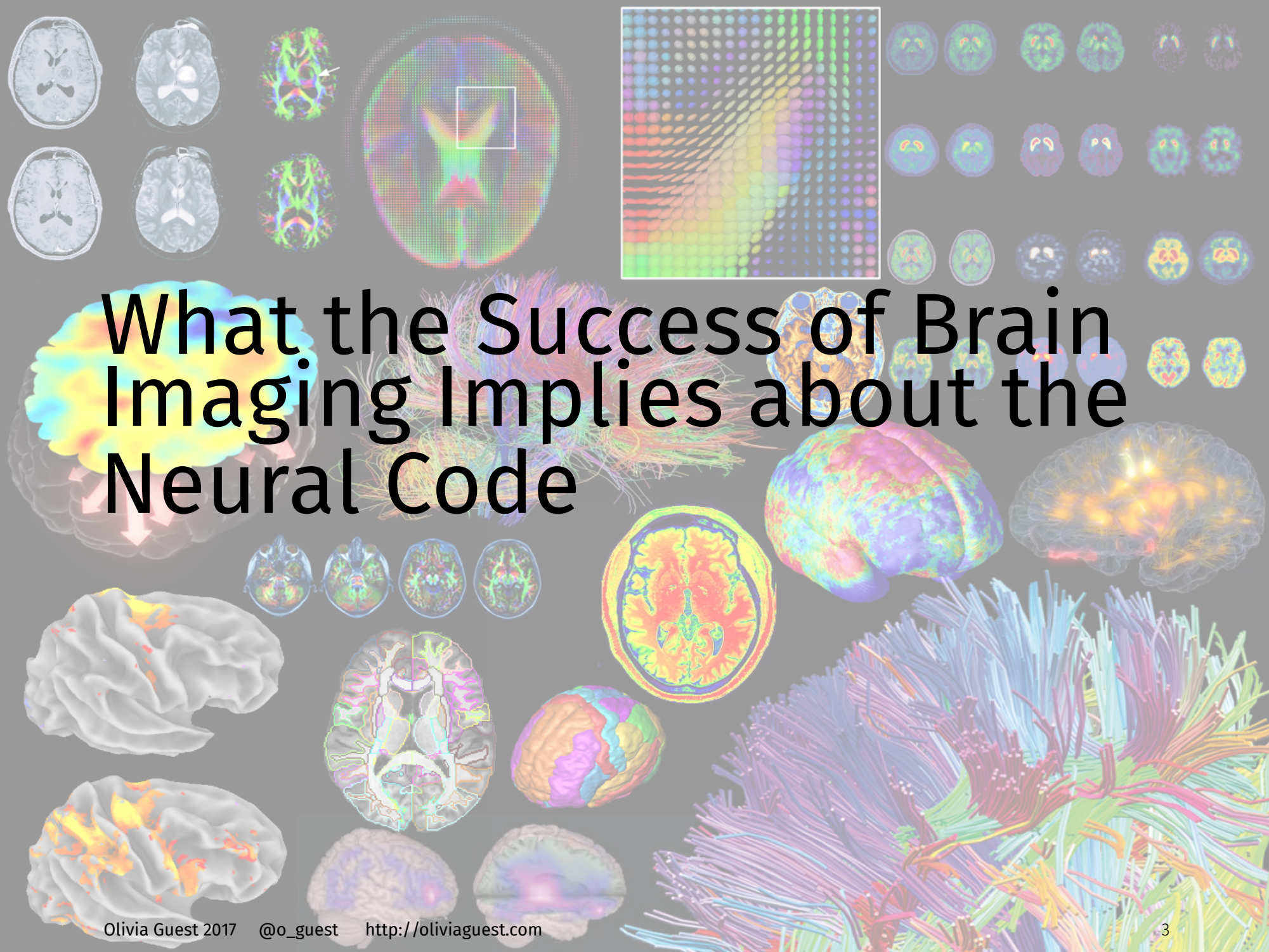
February 9, 2017

LJDM Seminar Series, University College London

COLLABORATOR

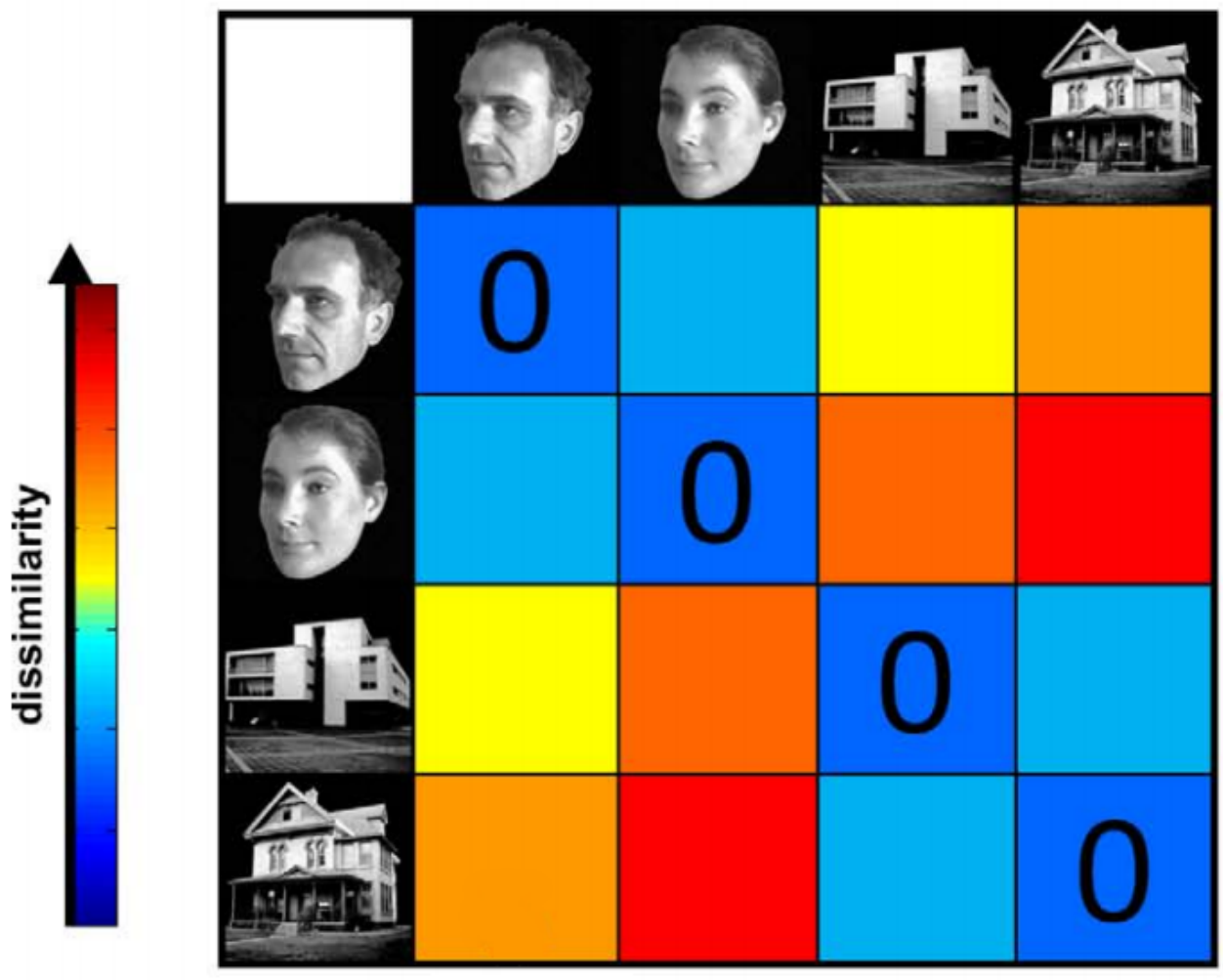
Bradley C. Love

University College London

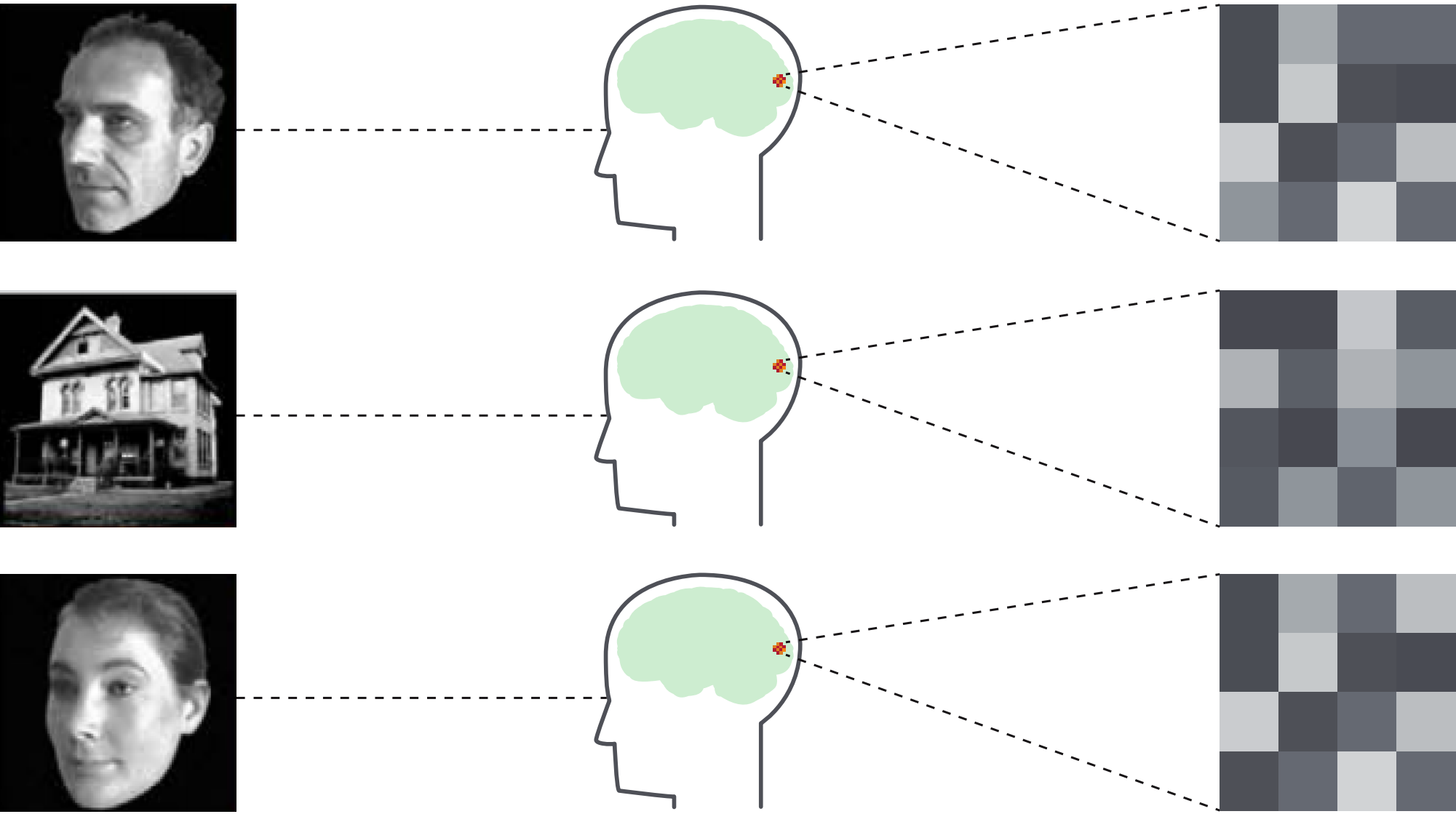


What the Success of Brain Imaging Implies about the Neural Code

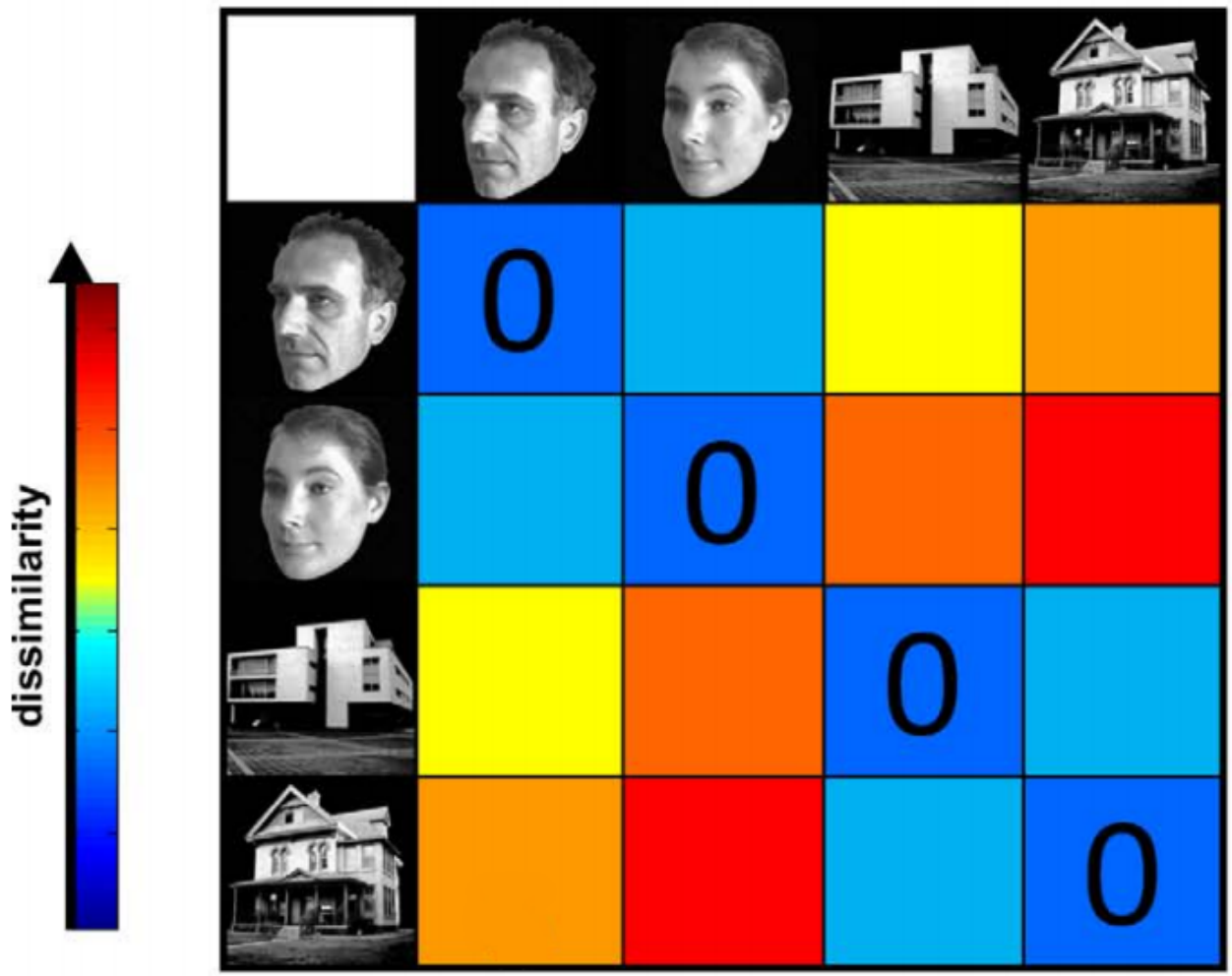
REPRESENTATIONAL SIMILARITY ANALYSIS (RSA)



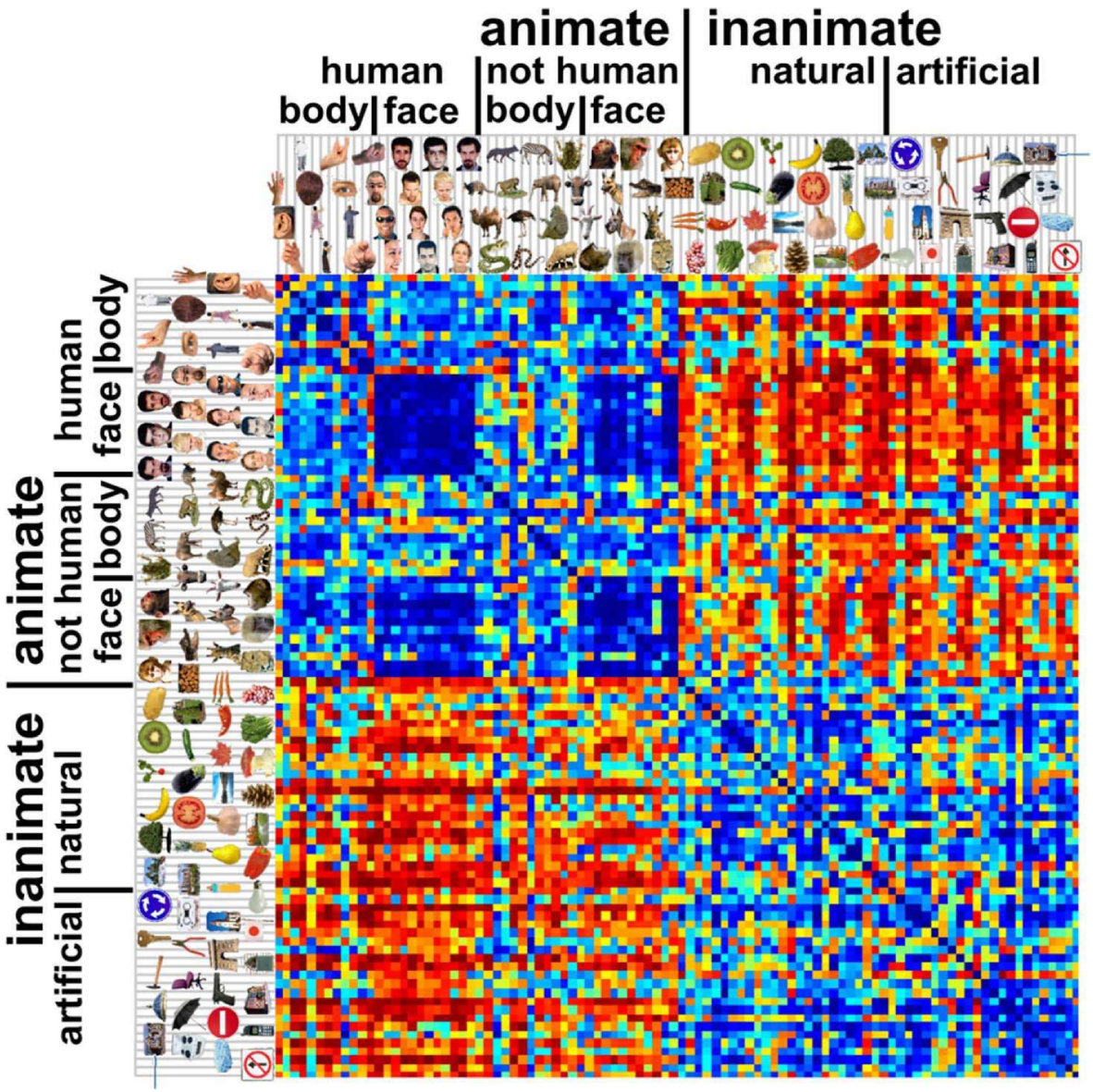
MULTIVARIATE PATTERN ANALYSIS (MVPA)



REPRESENTATIONAL SIMILARITY ANALYSIS (RSA)

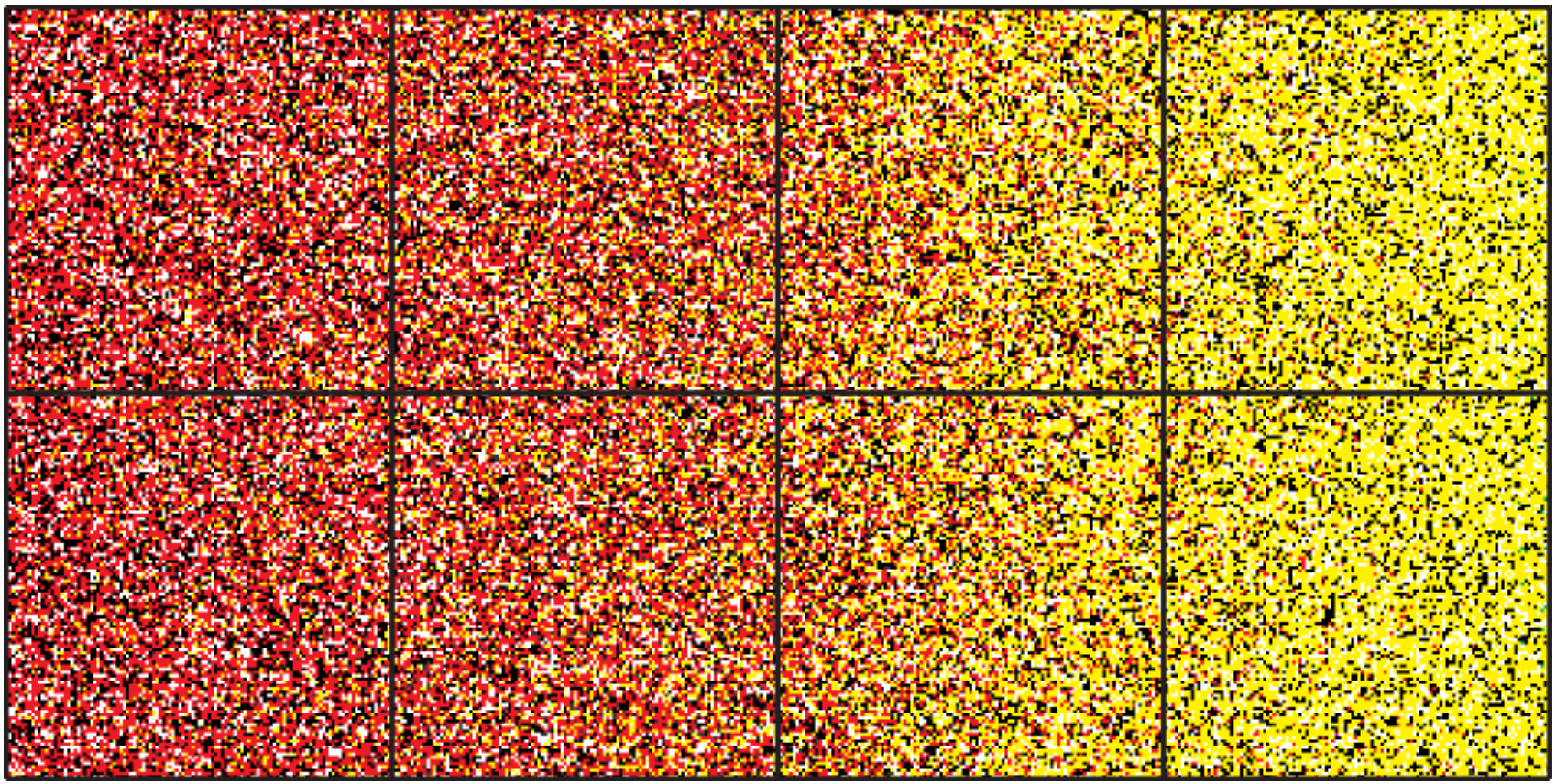


RSA: FUNCTIONAL SMOOTHNESS



Kriegeskorte, N. et al. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron.

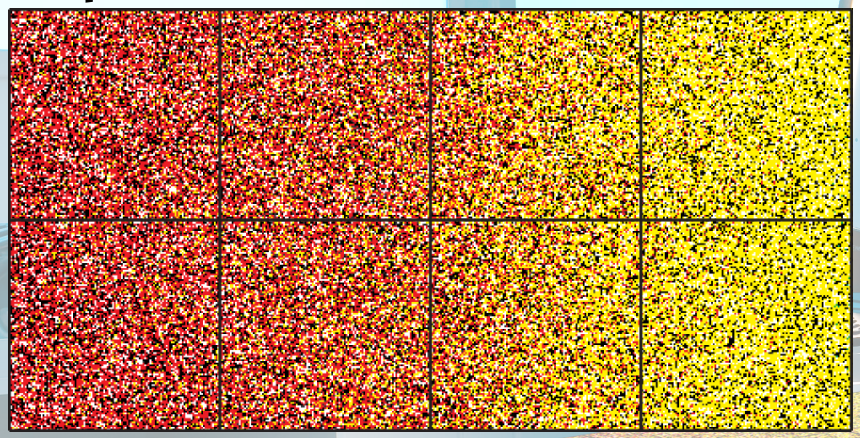
TOY FMRI



TOY FMRI

TOY FMRI

Input



Output

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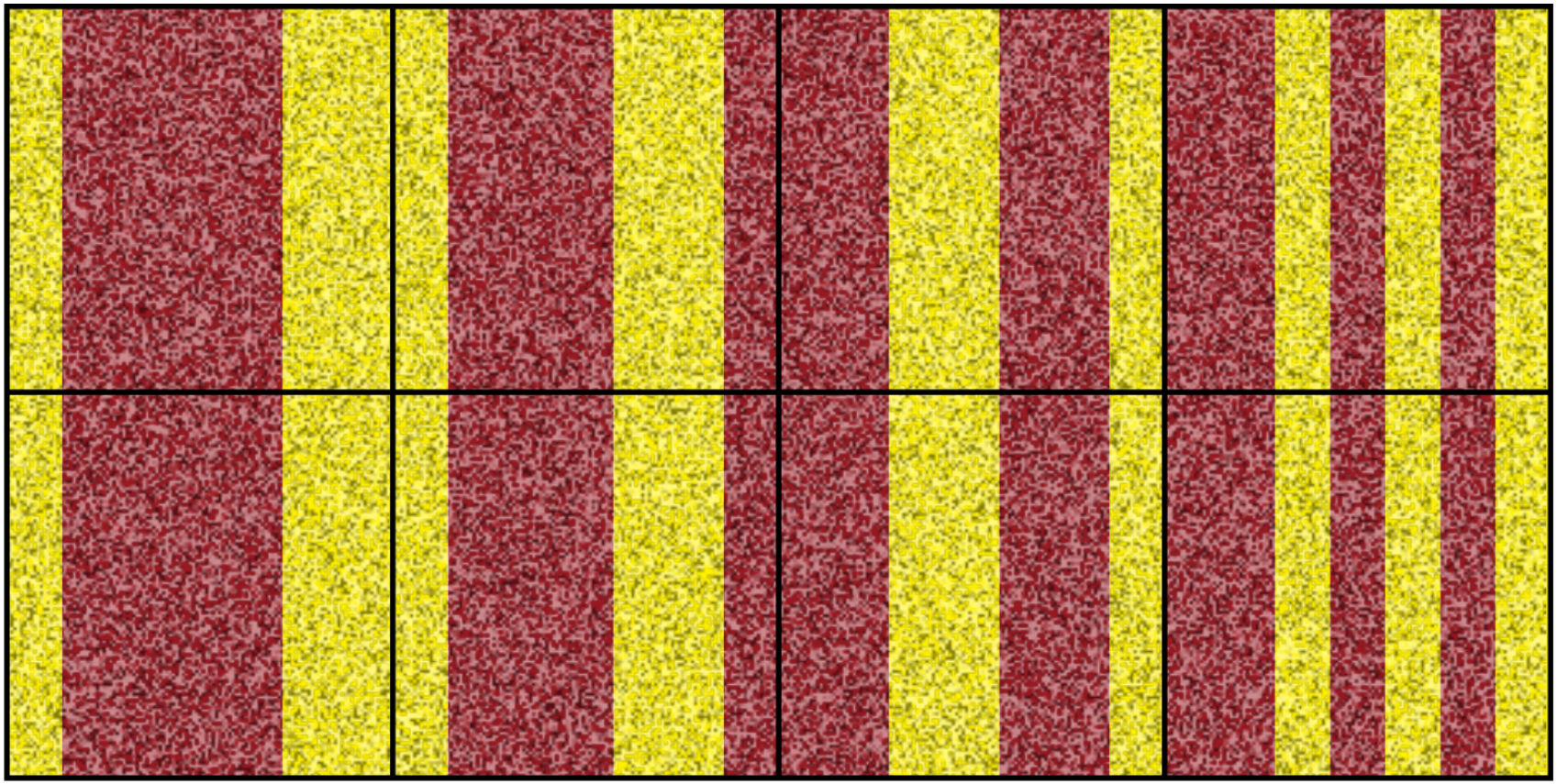
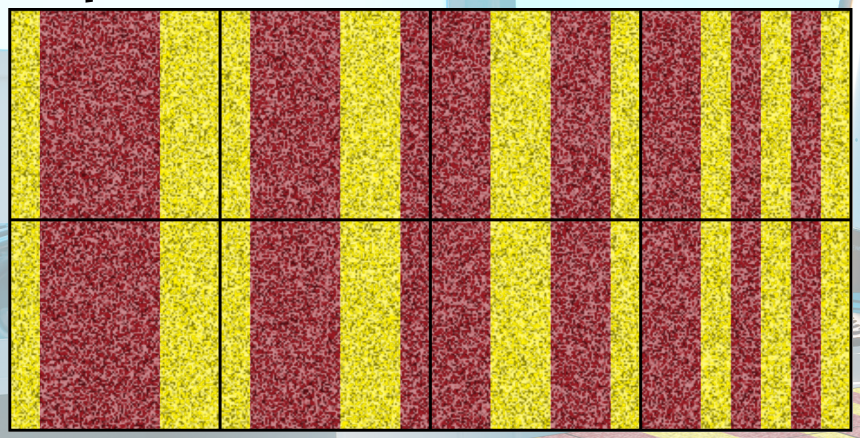


TOY FMRI

TOY FMRI

Input



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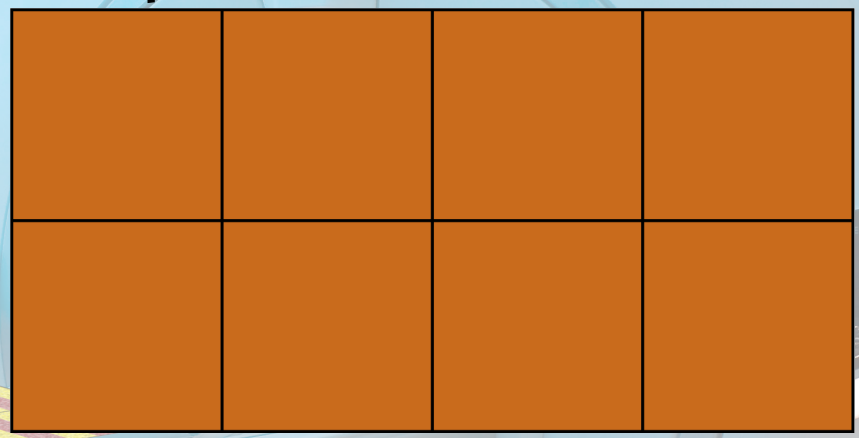
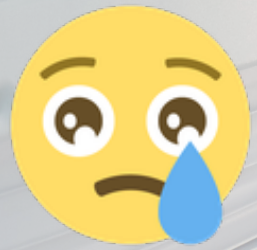




SMOOTHNESSES

- sub-voxel smoothness

SMOOTHNESSES

- sub-voxel smoothness

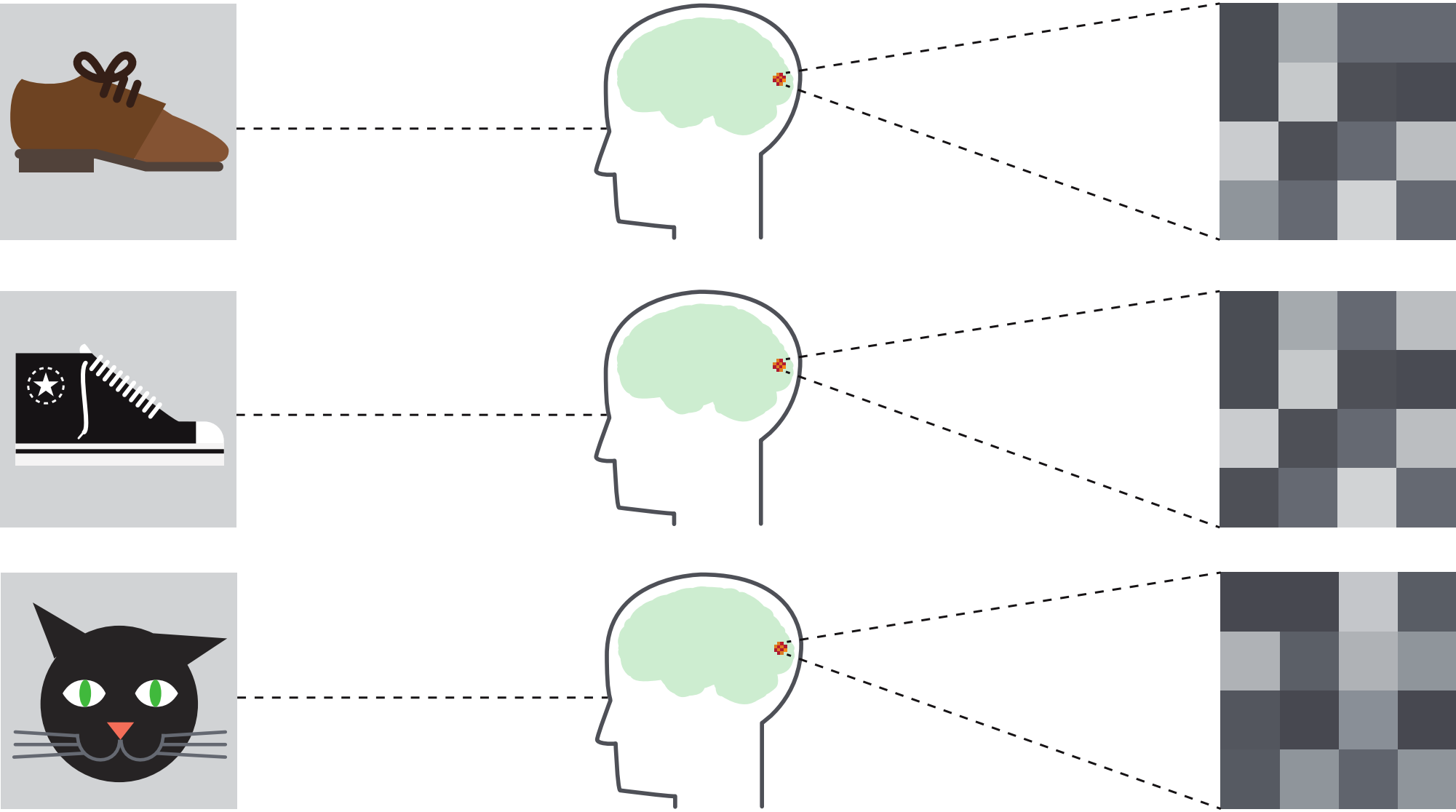
- super-voxel smoothness

SMOOTHNESSES

- sub-voxel smoothness
- super-voxel smoothness
- functional smoothness:

  $\mathrm{sim}(x_a, x_b) \propto \mathrm{sim}(y_a, y_b)$

FUNCTIONAL SMOOTHNESS



CODES THAT DO NOT WORK

- hash function coding
- burstiness coding
- factorial design coding

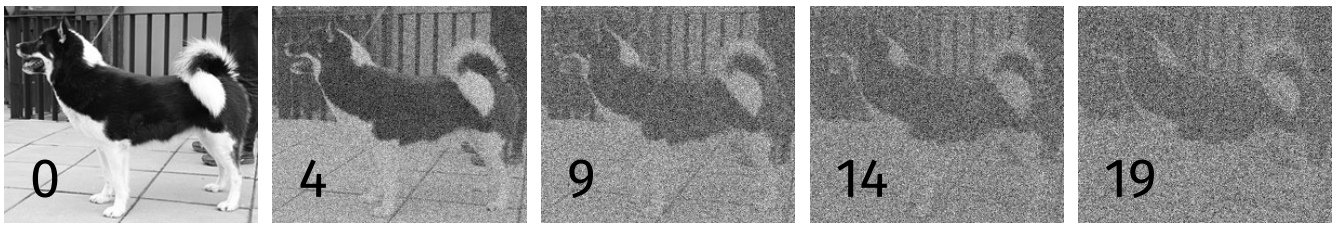
CODES THAT DO NOT WORK

Factorial design:

- columns = features
- orthogonal representations

I	A	B	C	AB	AC	BC	ABC
1	−1	−1	−1	1	1	1	−1
1	1	−1	−1	−1	−1	1	1
1	−1	1	−1	−1	1	−1	1
1	1	1	−1	1	−1	−1	−1
1	−1	−1	1	1	−1	−1	1
1	1	−1	1	−1	1	−1	−1
1	−1	1	1	−1	−1	1	−1
1	1	1	1	1	1	1	1

INPUT



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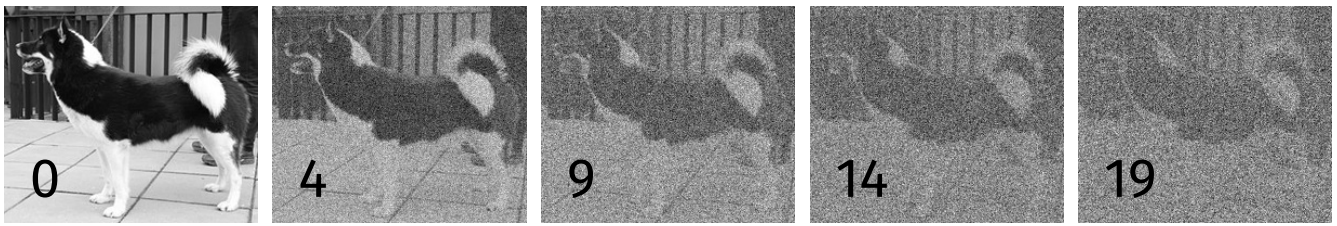
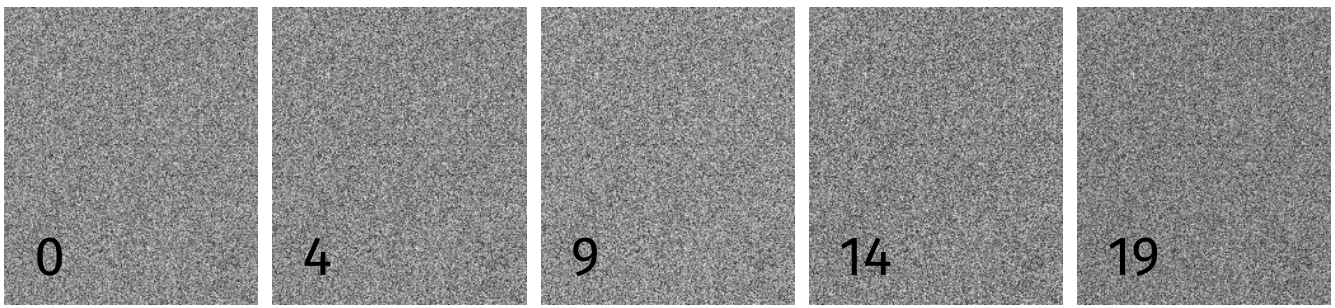




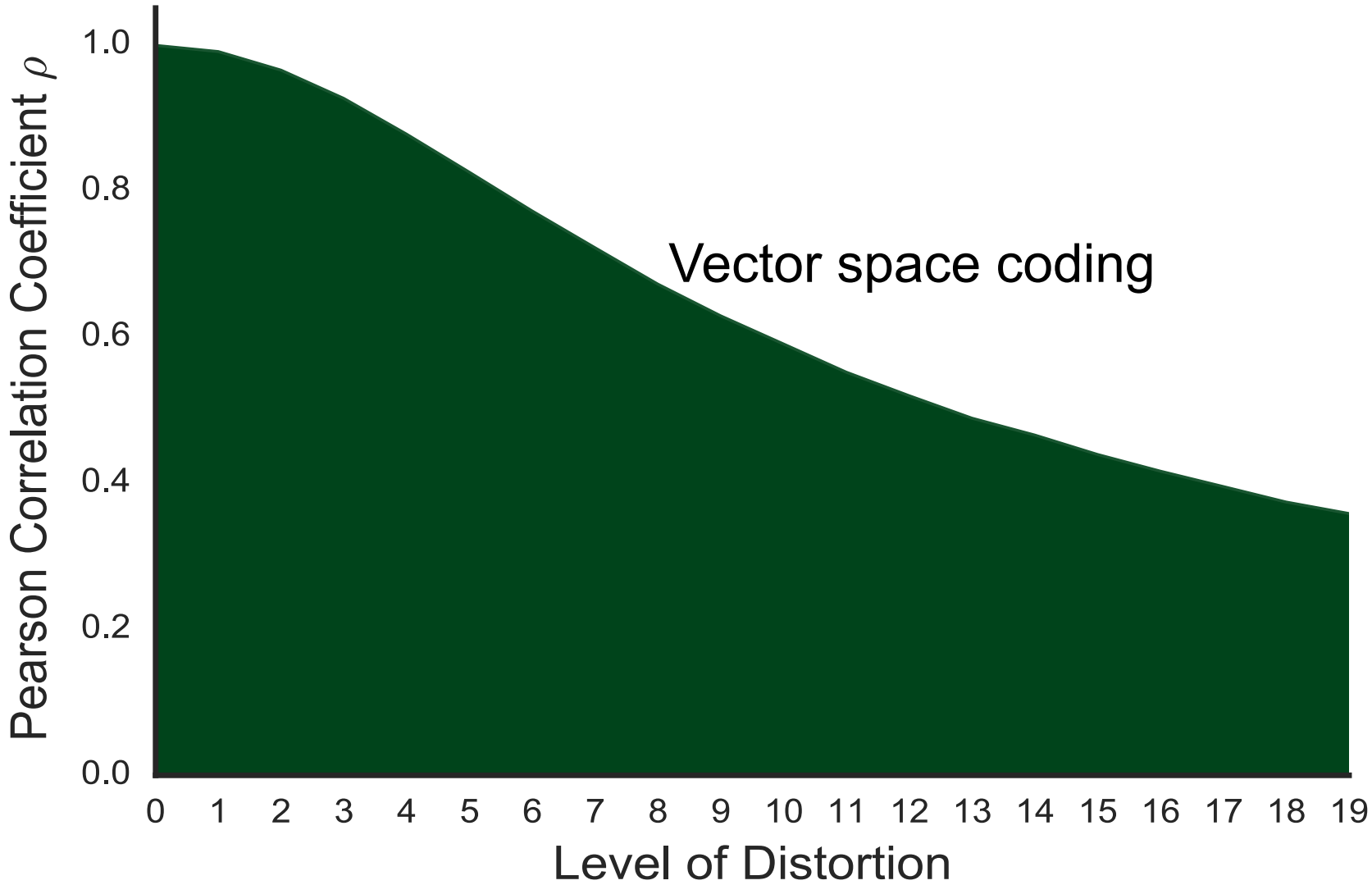
CODES THAT WORK

- vector space coding
- matrix multiplication coding
- perceptron coding
- multiple layer network coding

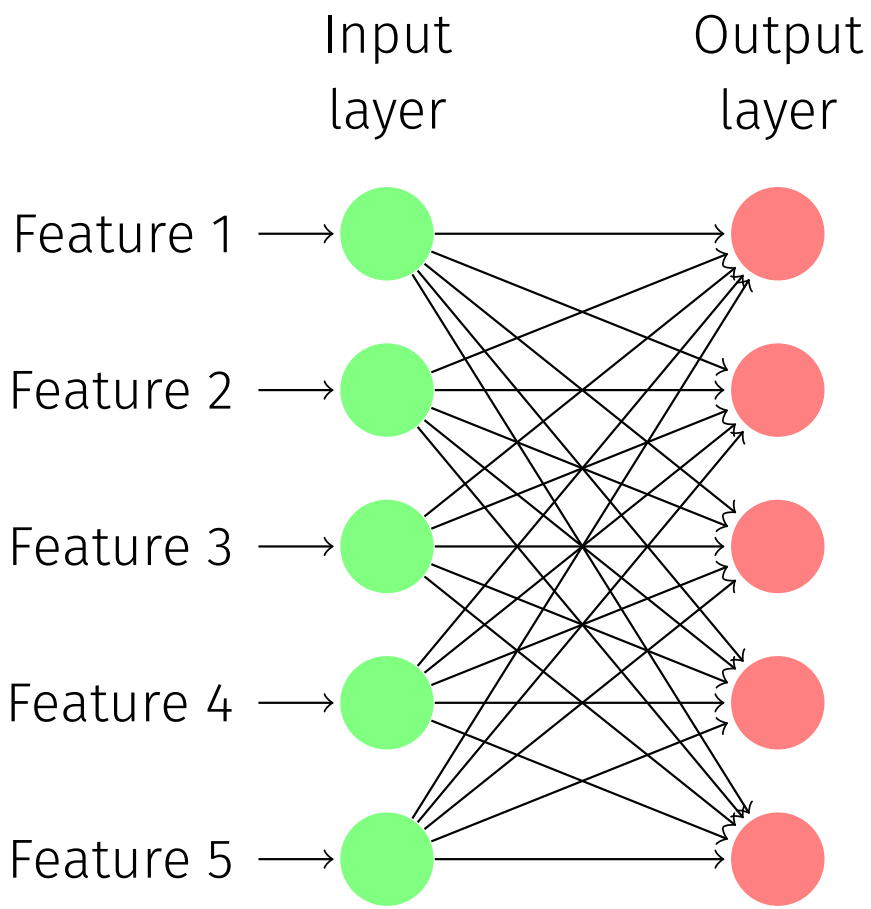
VECTOR SPACE CODING

$$235 \times 200 = 47000$$

VECTOR SPACE CODING



MATRIX MULTIPLICATION CODING



MATRIX MULTIPLICATION CODING

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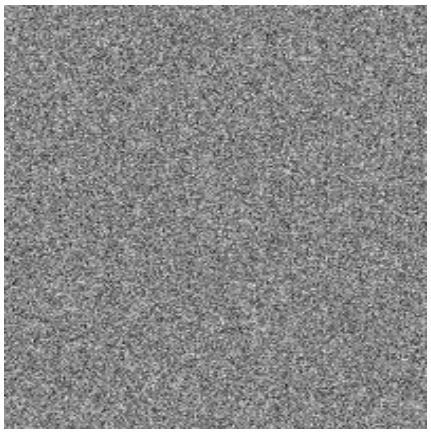

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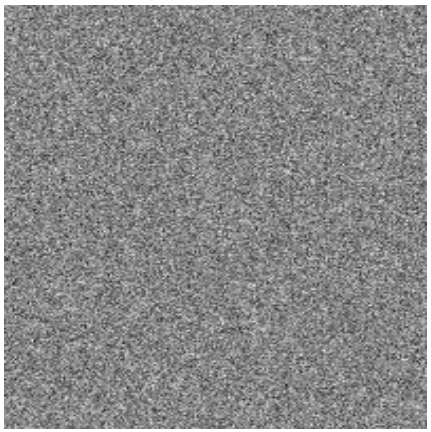
MATRIX MULTIPLICATION CODING



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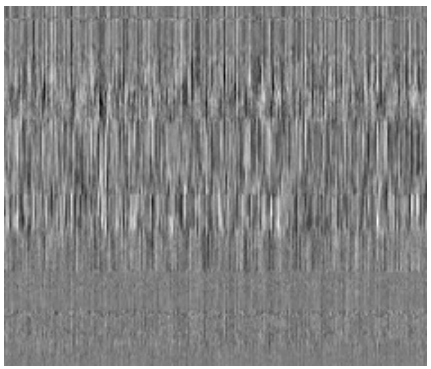

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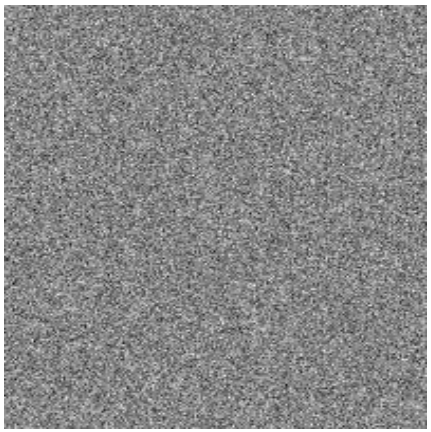

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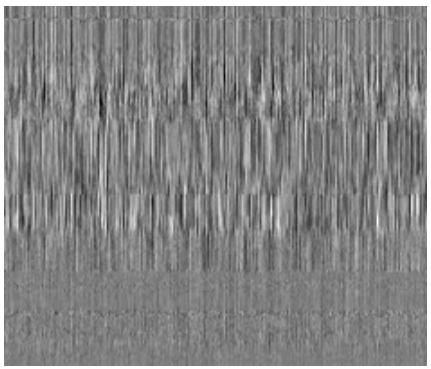
tanh



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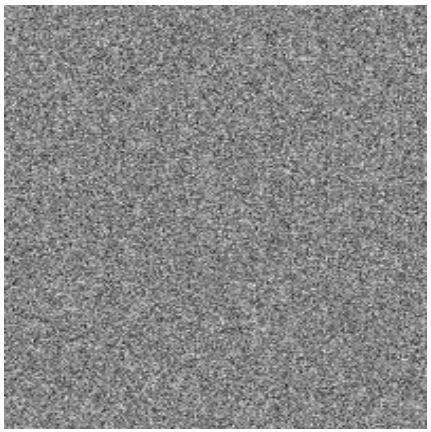

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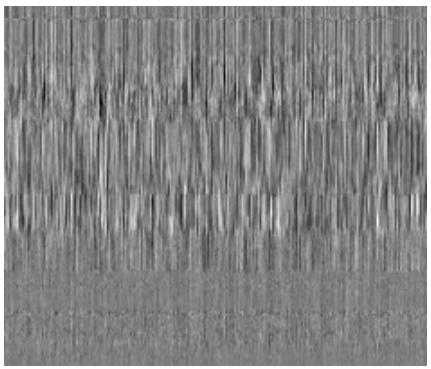

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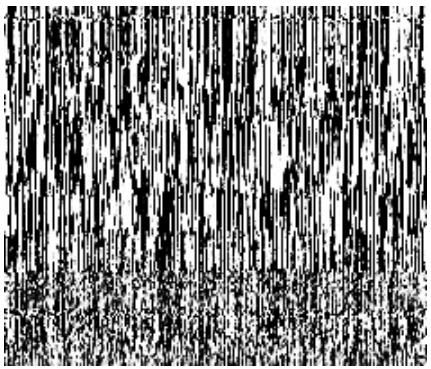
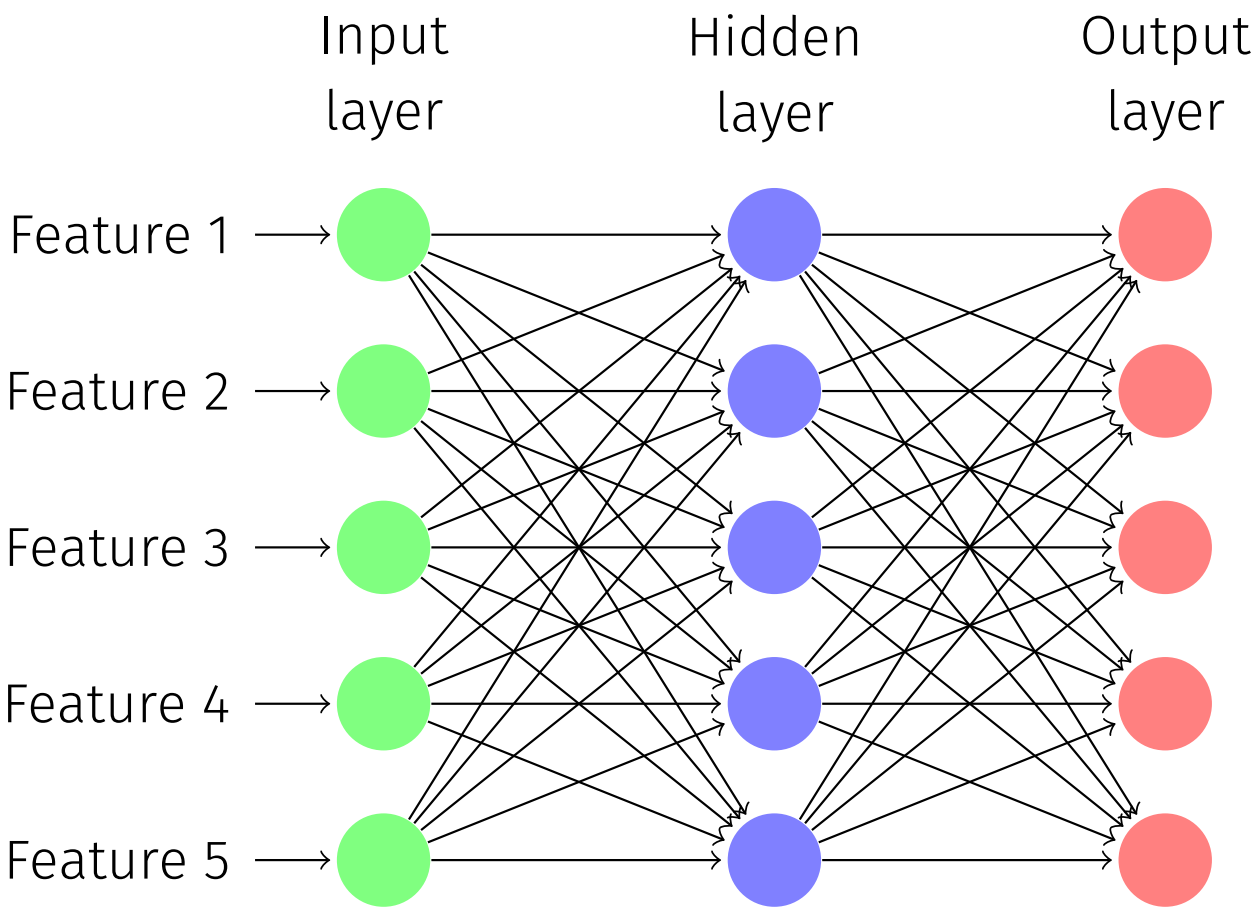
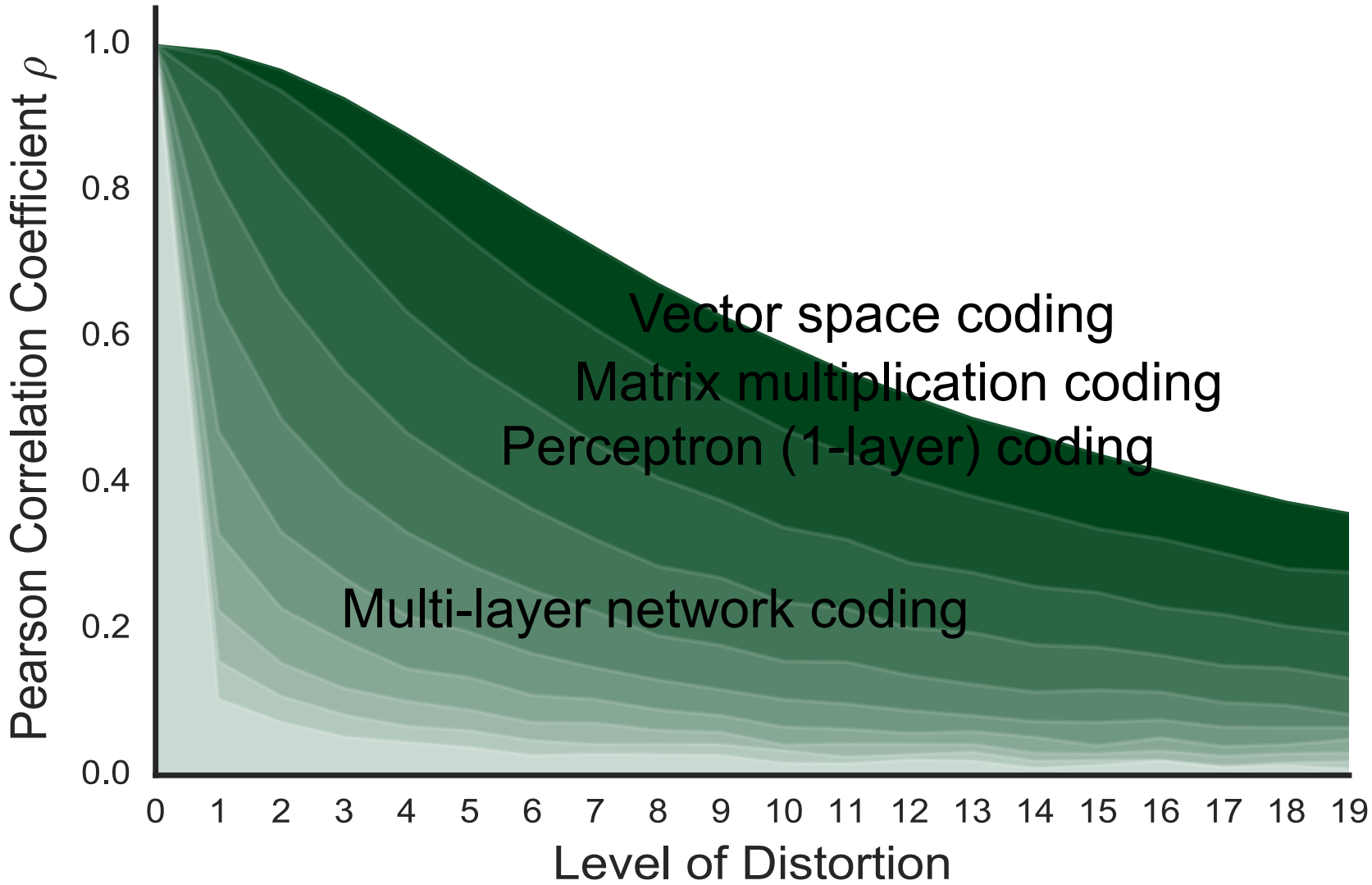


ARTIFICIAL NEURAL NETWORK CODING



DEEP NETWORK CODING



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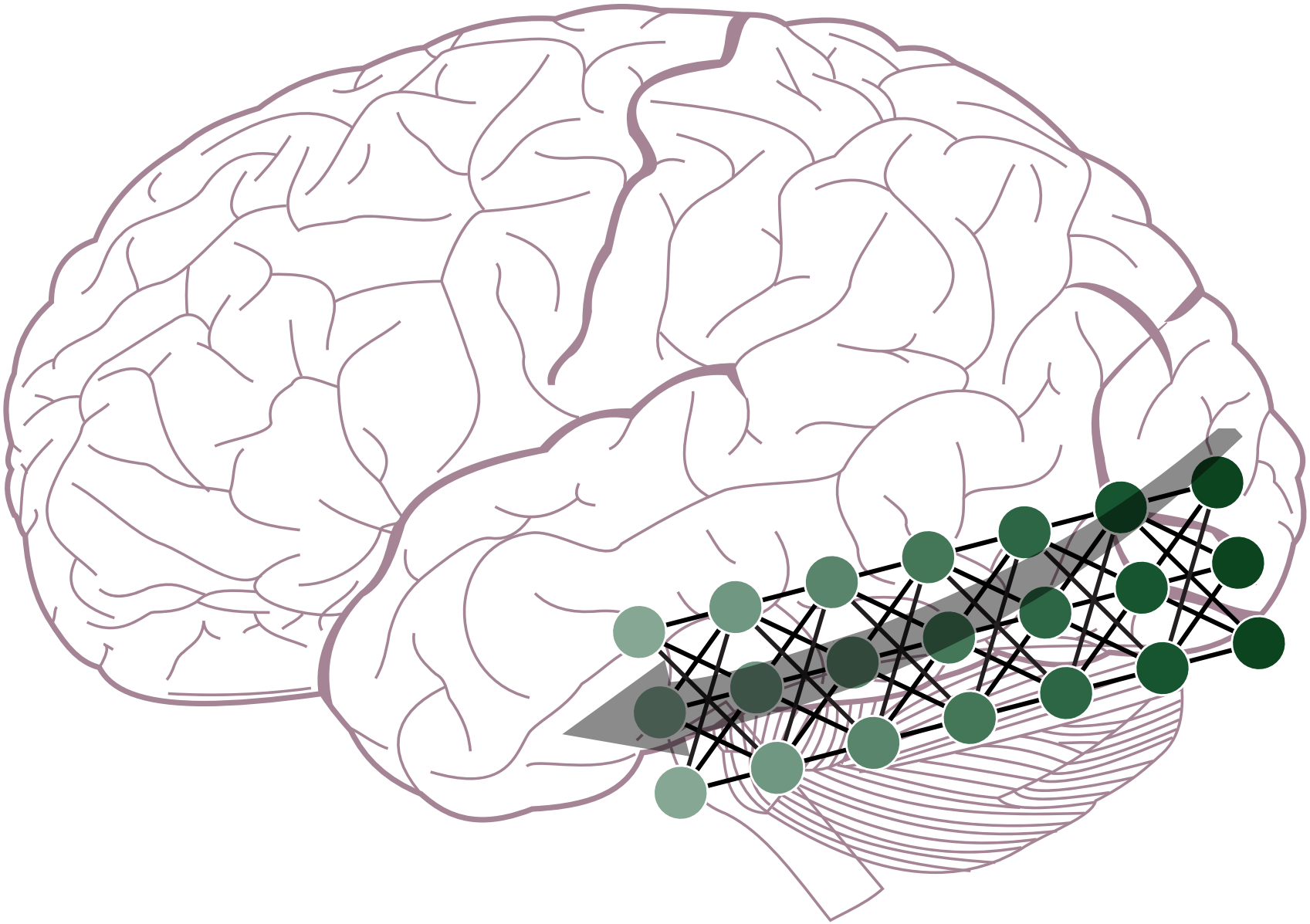
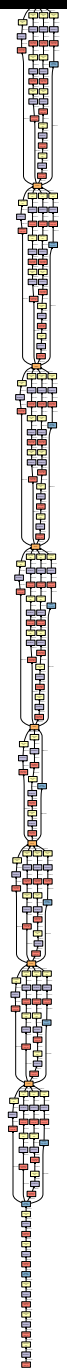
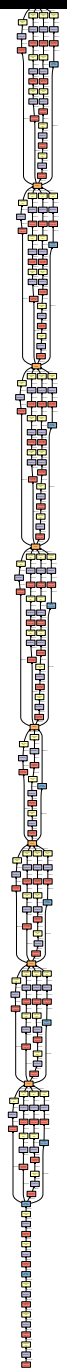


DEEP NETWORK CODING



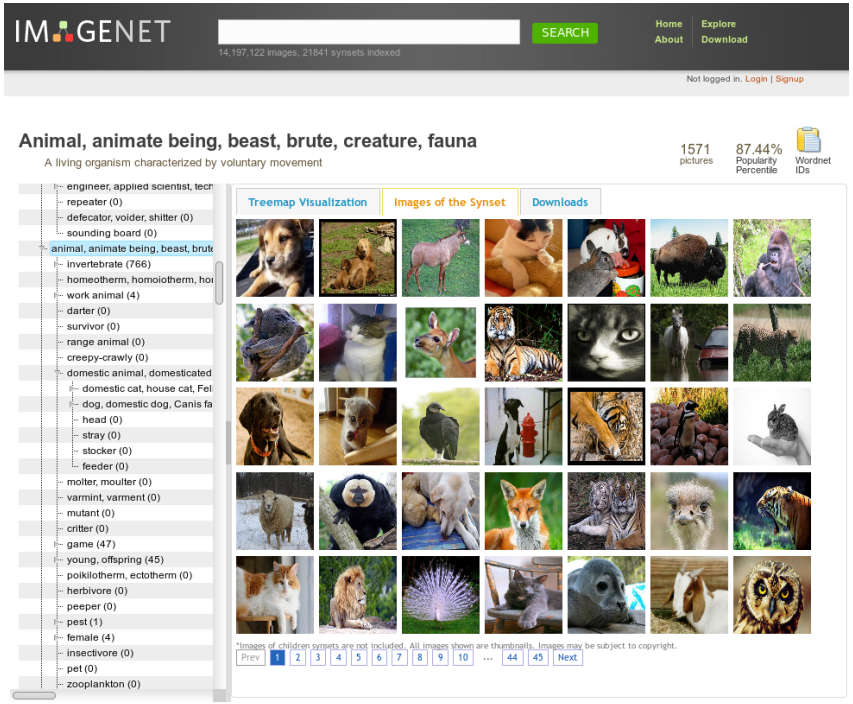
DEEP NETWORK CODING

- Inception v3
  GoogleNet
- 25 million parameters
- 3.5% top-5 error

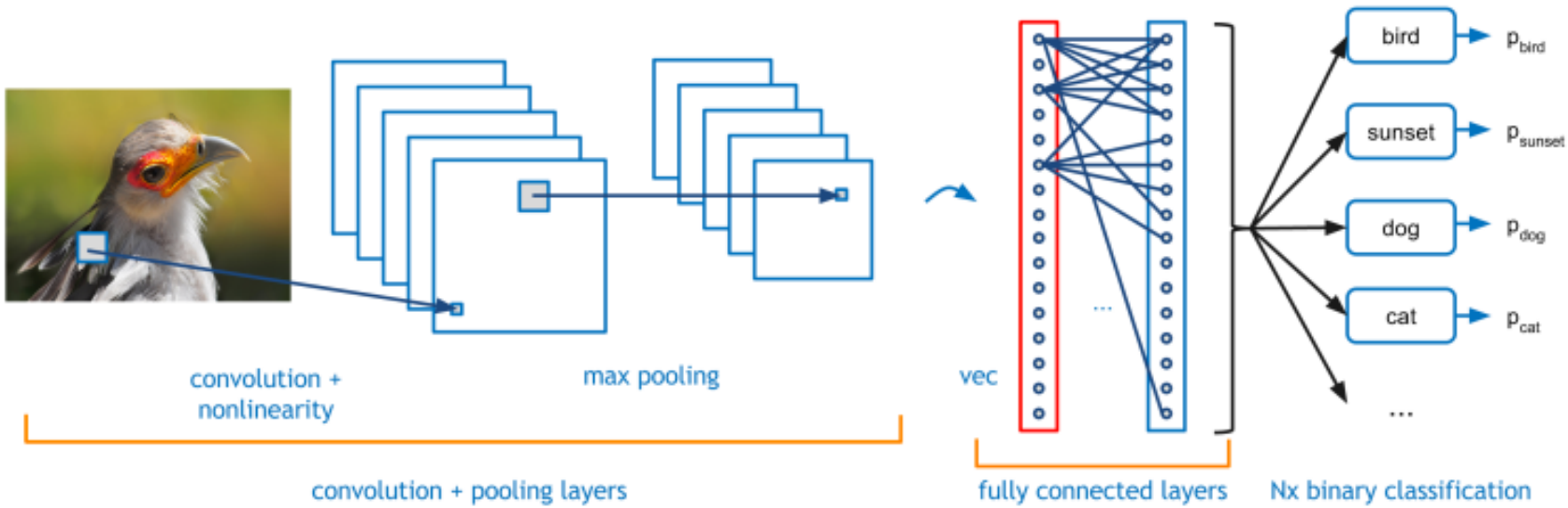


DEEP NETWORK CODING

- trained on millions of photos
- 1000 categories



DEEP NETWORK CODING



DEEP NETWORK CODING

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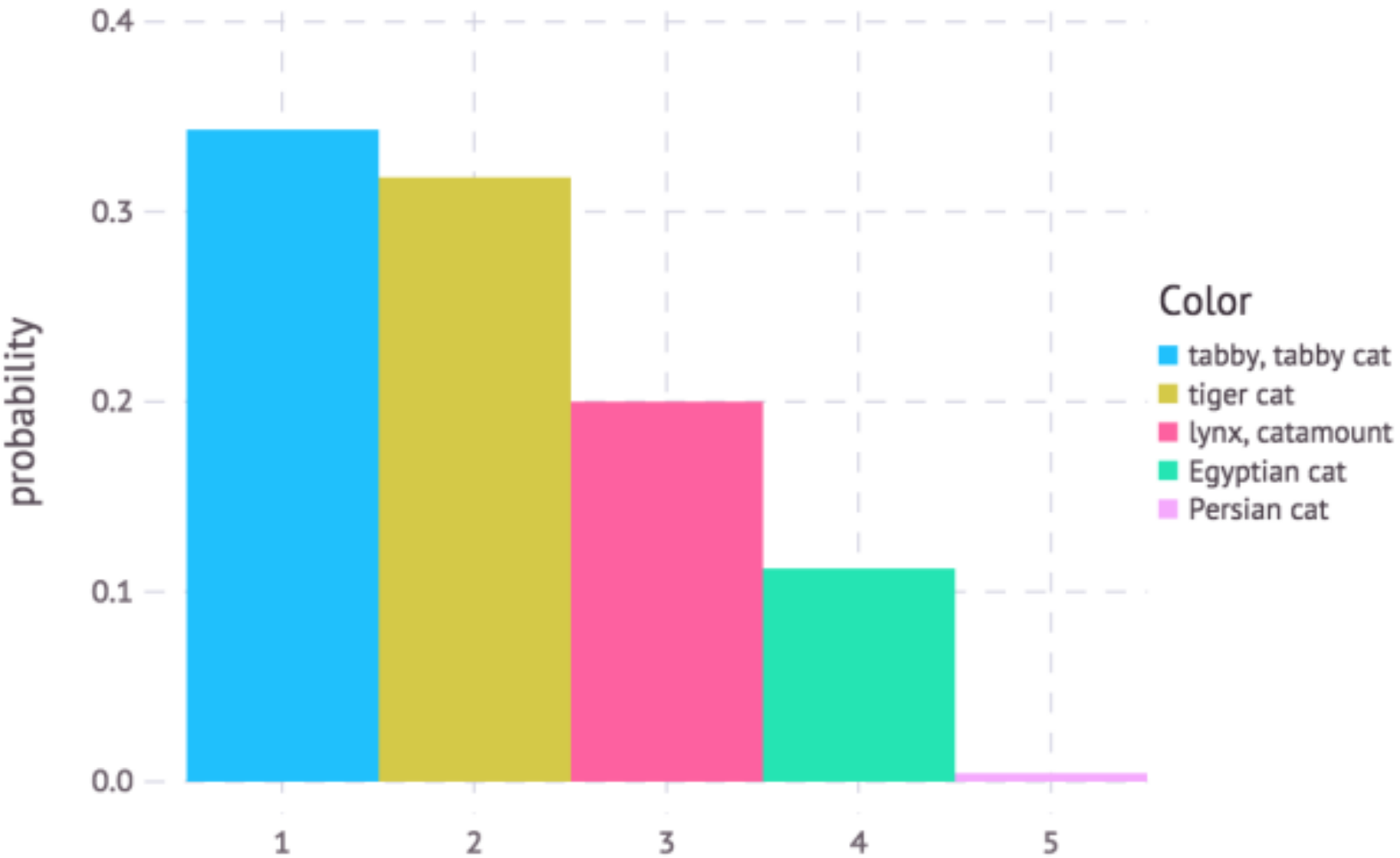

- dust cover: 44.9%
- comic book: 14.7%
- throne: 7.8%
- pyjama: 4.4%
- suit: 3.6%

DEEP NETWORK CODING

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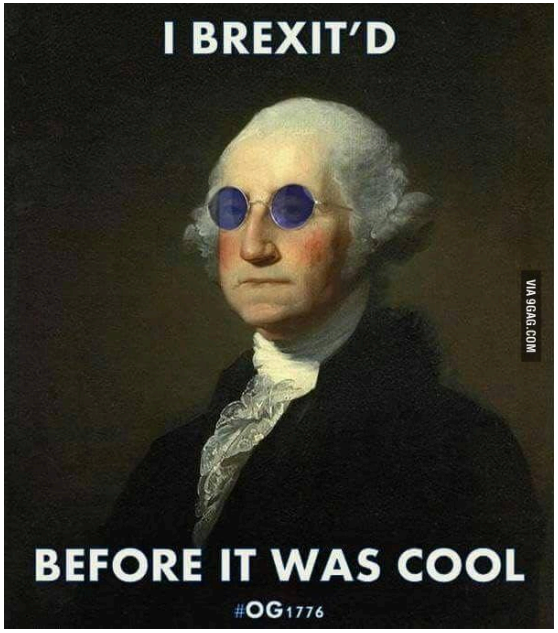
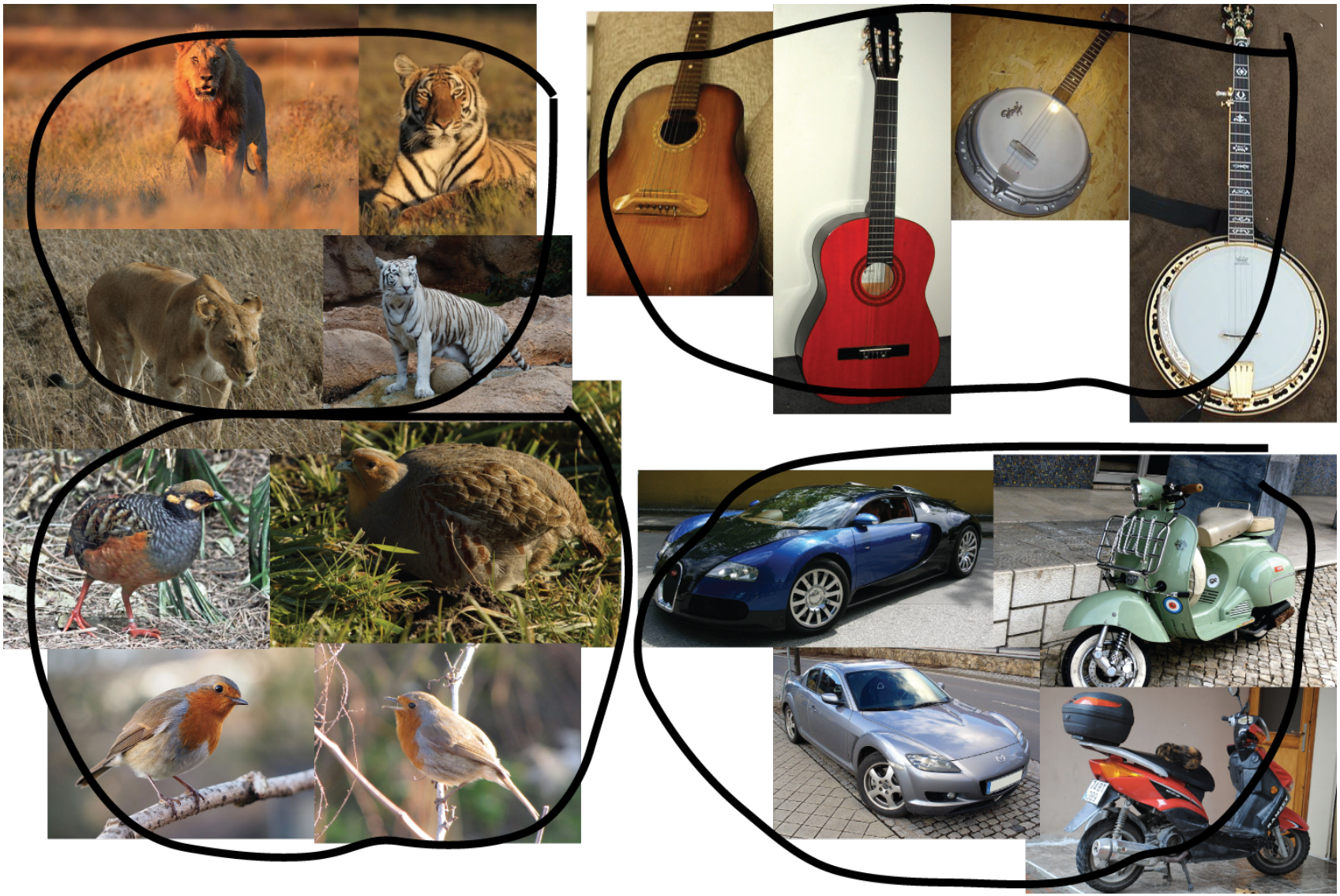


- sunglasses: 40.7%
- wig: 8.4%
- sunglass: 7.9%
- dust cover: 5.6%
- suit: 2.8%

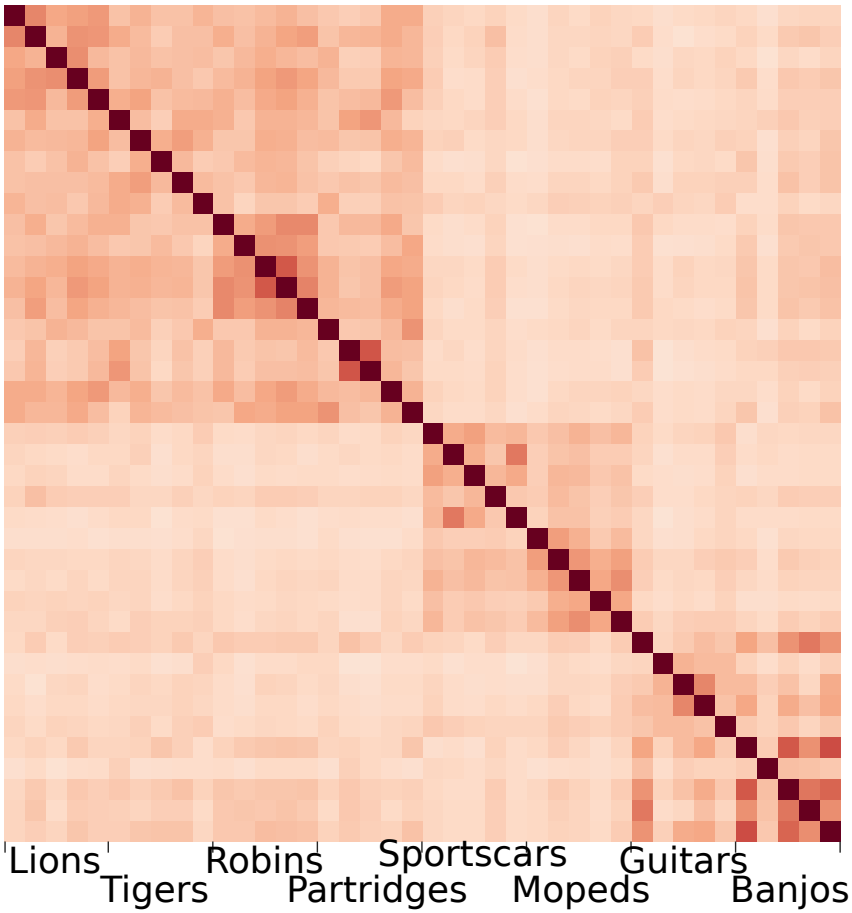
DEEP NETWORK CODING

DEEP NETWORK CODING

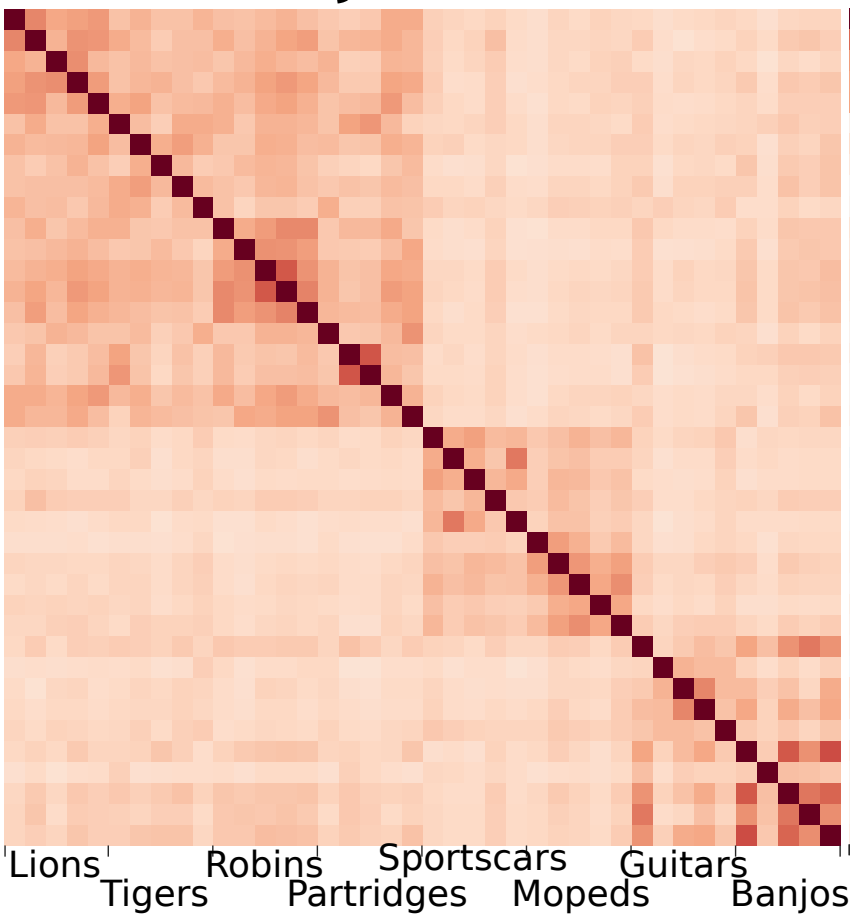


DEEP NETWORK CODING

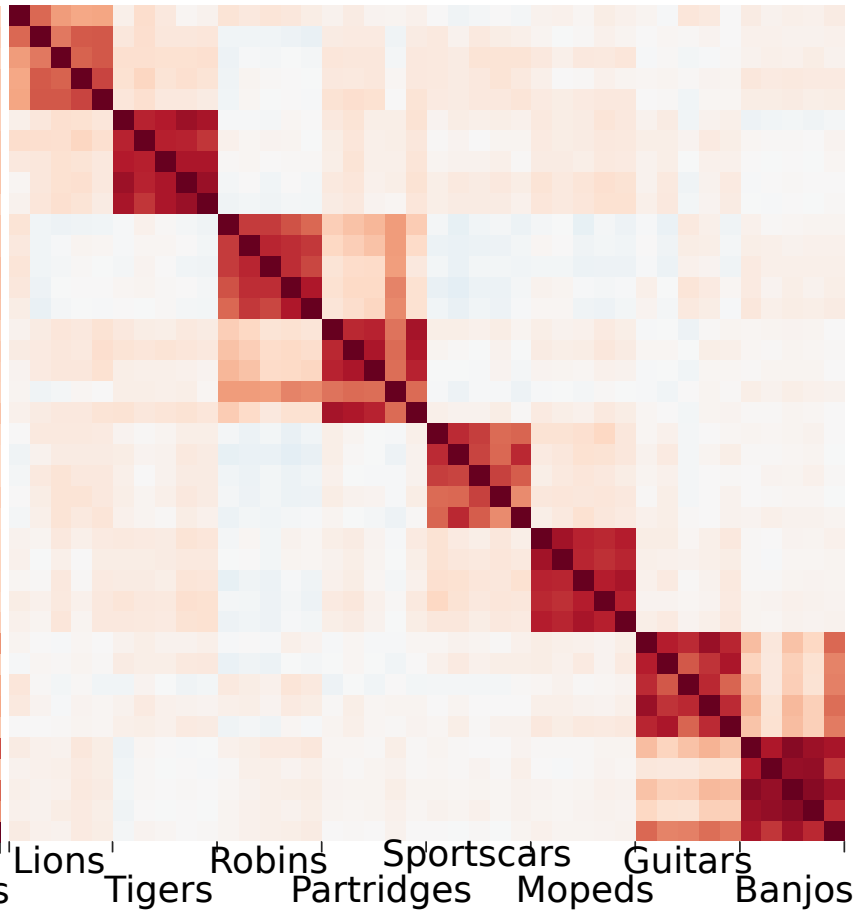
Earlier layer



Earlier layer



Later layer



CONCLUSIONS

- Success of fMRI constrains the nature of the neural code
- Connectionist models are consistent with the success of fMRI
- Deep belief networks behave similarly

CONCLUSIONS

- Subvoxel and functional smoothness are required for fMRI
- Functional smoothness breaks down at advanced network layers
- Ergo might be harder to uncover similarity in “advanced” brain regions

Thanks for listening!

- wig: 99.0%
- sunglasses: << 0.01%
- wool: << 0.01%
- sunglass: << 0.01%
- hair spray: << 0.01%

Thanks for listening!

- wig: 99.0%
- sunglasses: << 0.01%
- wool: << 0.01%
- sunglass: << 0.01%
- hair spray: << 0.01%

- hoopskirt: 13.3%
- lab coat: 10.3%
- groom: 8.6%
- vestment: 2.8%
- toilet paper: 2.7%

THE END OF THE WORLD

- academic gown: 68.3%
- mortarboard: 11.1%
- vestment: 5.0%
- Windsor tie: 0.4%
- ice lolly: 0.4%