WHAT THE SUCCESS OF BRAIN IMAGING IMPLIES ABOUT THE NEURAL CODE

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March 8, 2017

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COLLABORATOR

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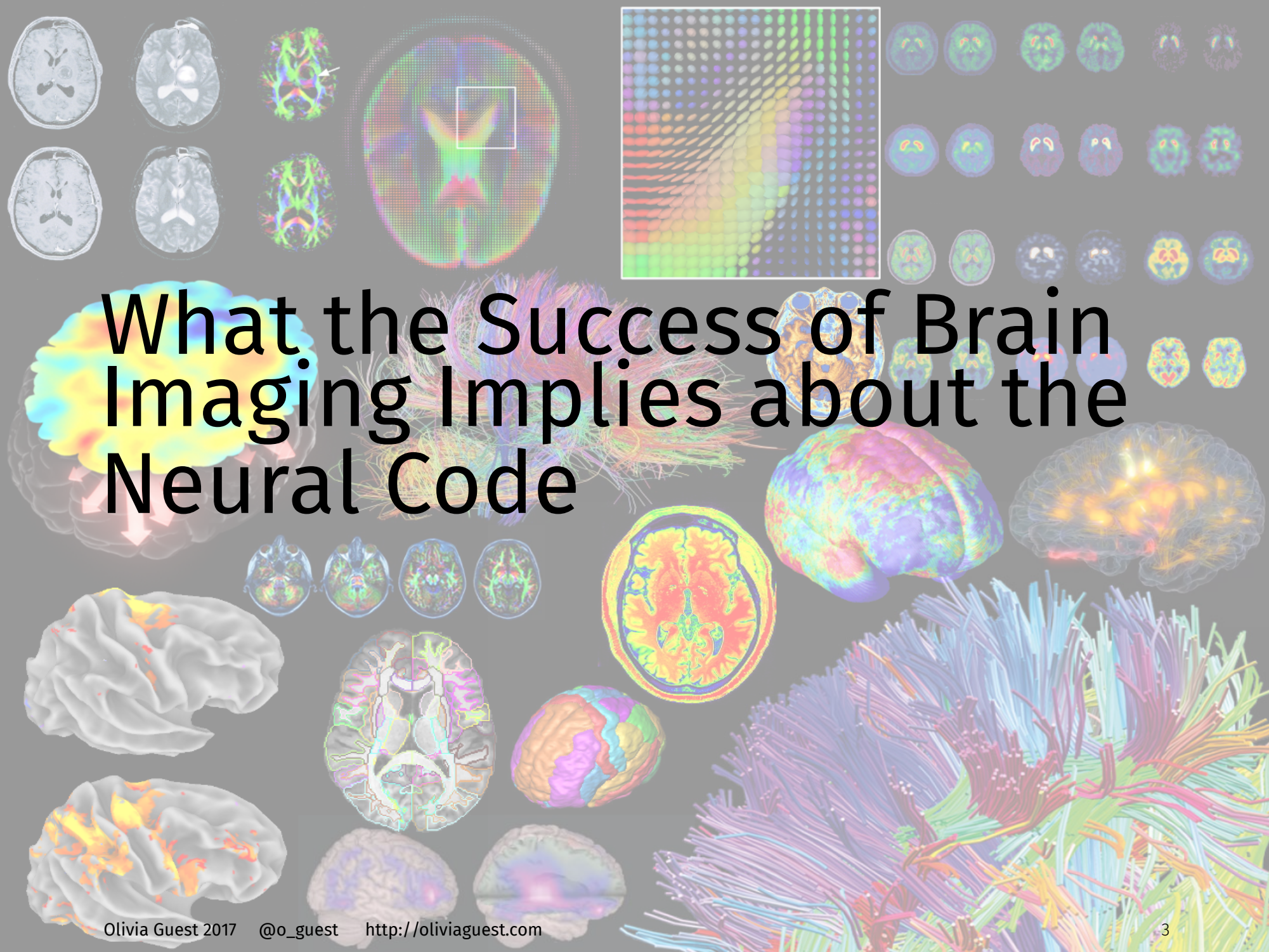
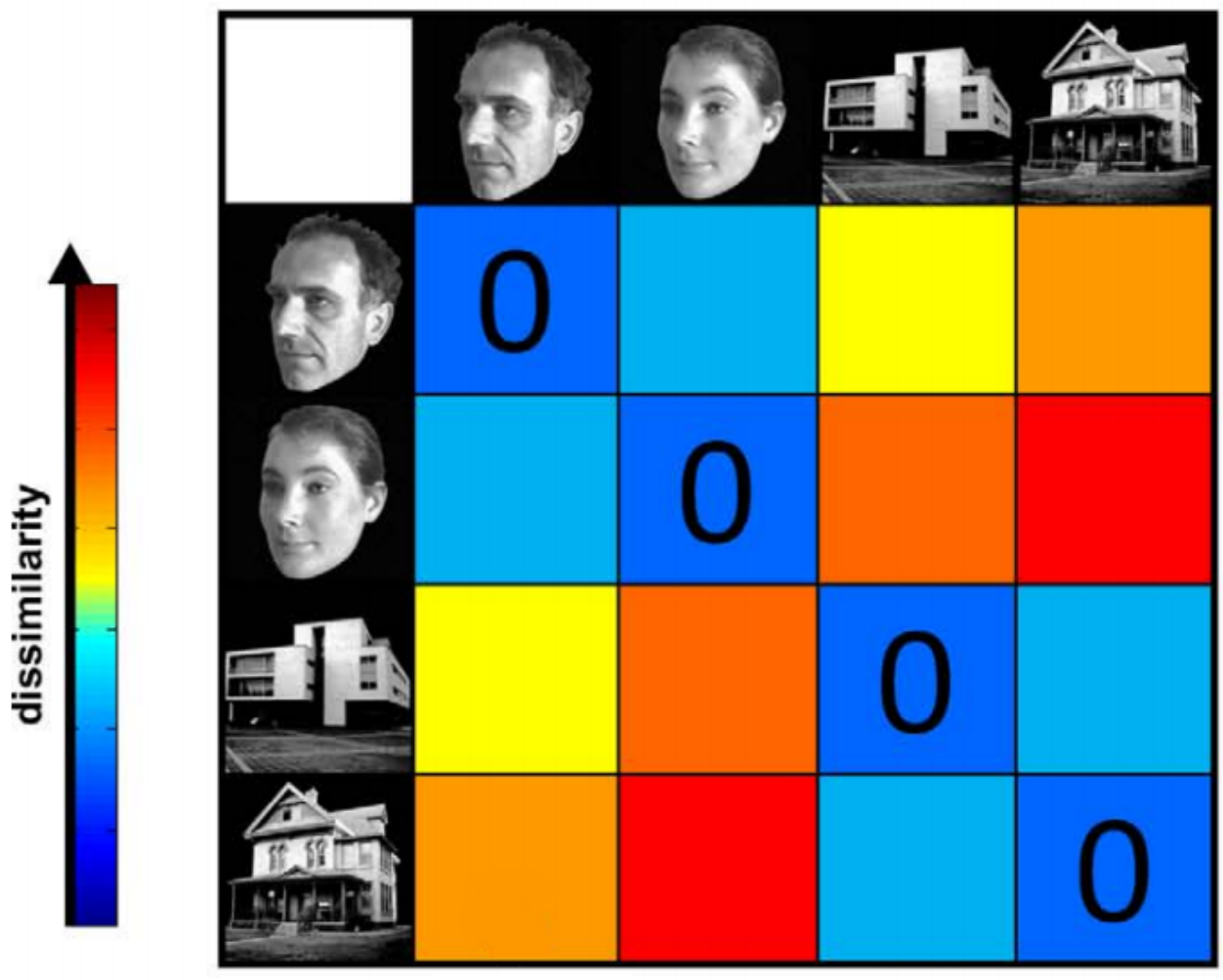
http://bradlove.org

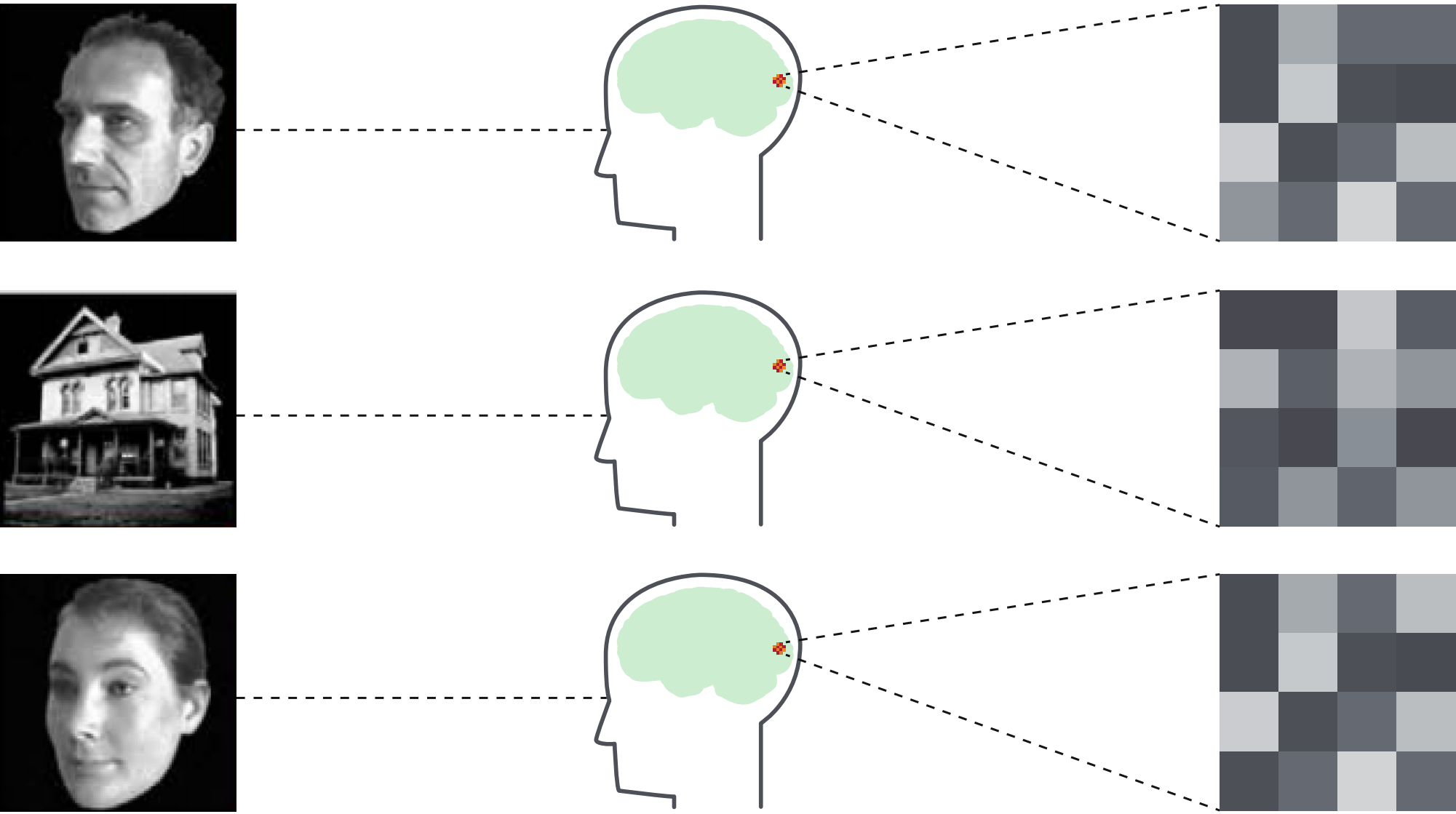


What the Success of Brain Imaging Implies about the Neural Code

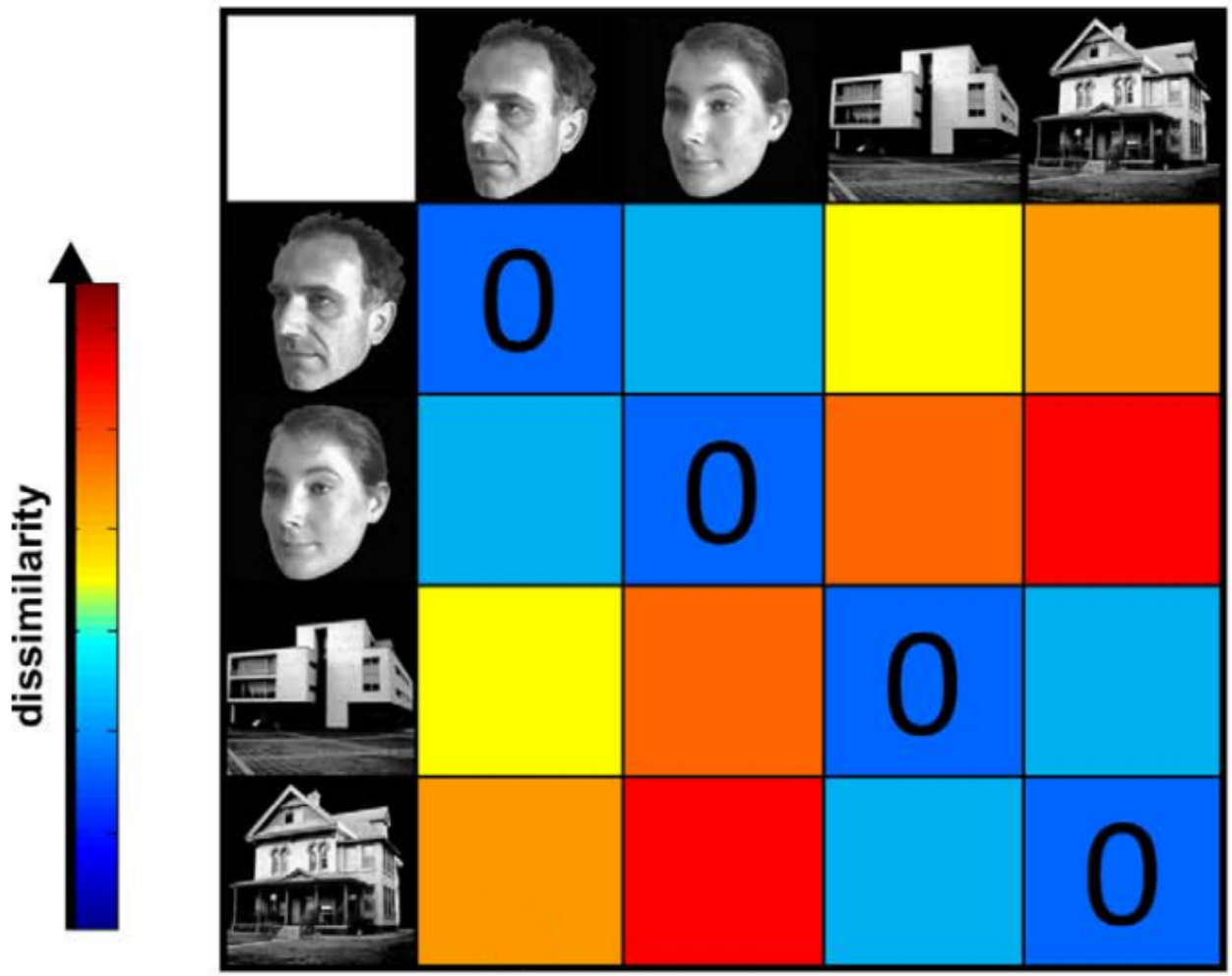
REPRESENTATIONAL SIMILARITY ANALYSIS (RSA)



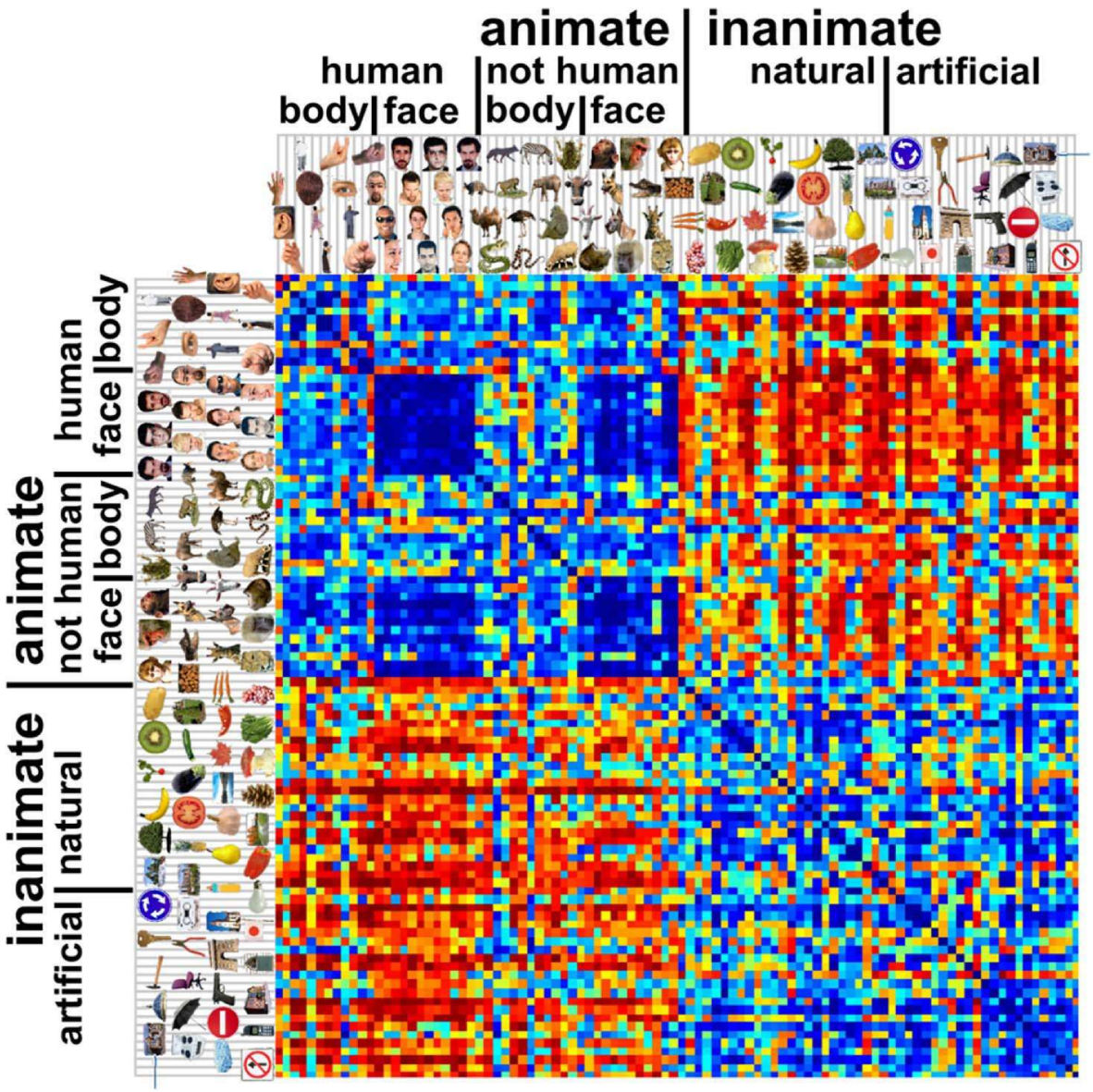
MULTIVARIATE PATTERN ANALYSIS (MVPA)



REPRESENTATIONAL SIMILARITY ANALYSIS (RSA)

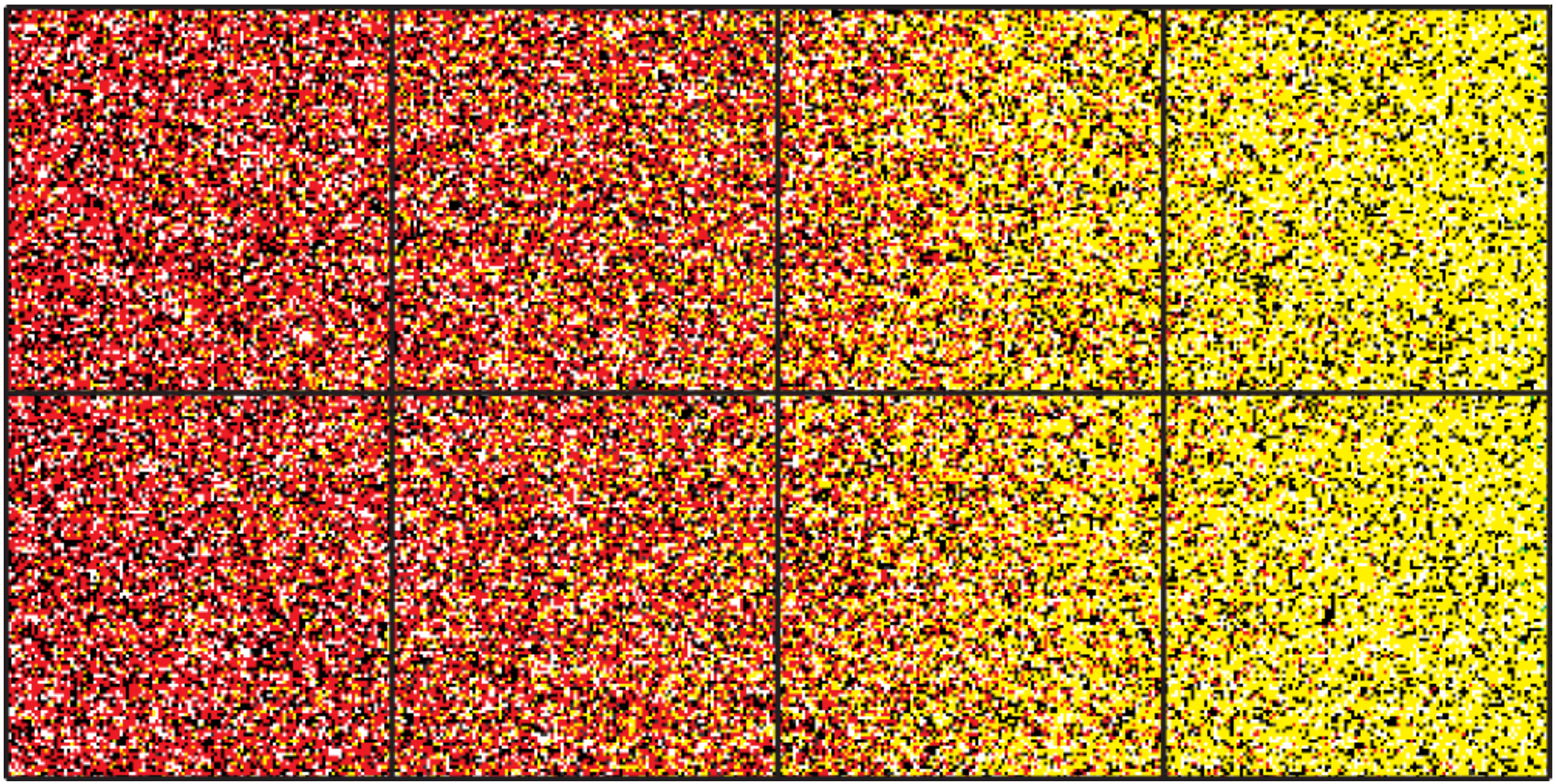


RSA: FUNCTIONAL SMOOTHNESS



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

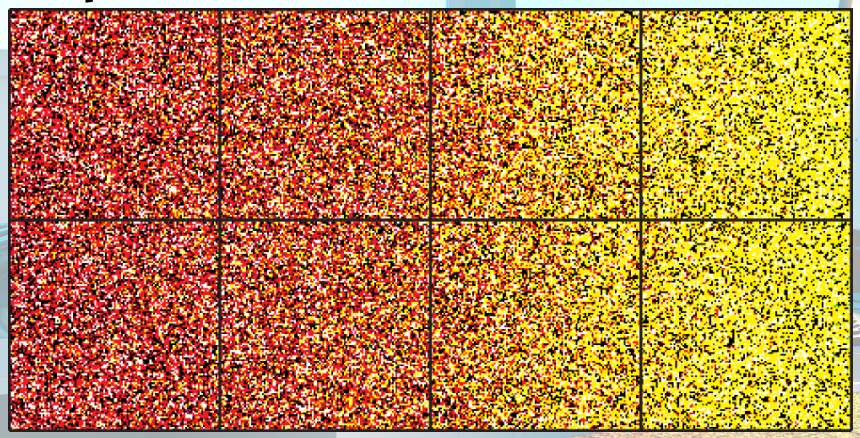
TOY FMRI



TOY FMRI

TOY FMRI

Input



Output

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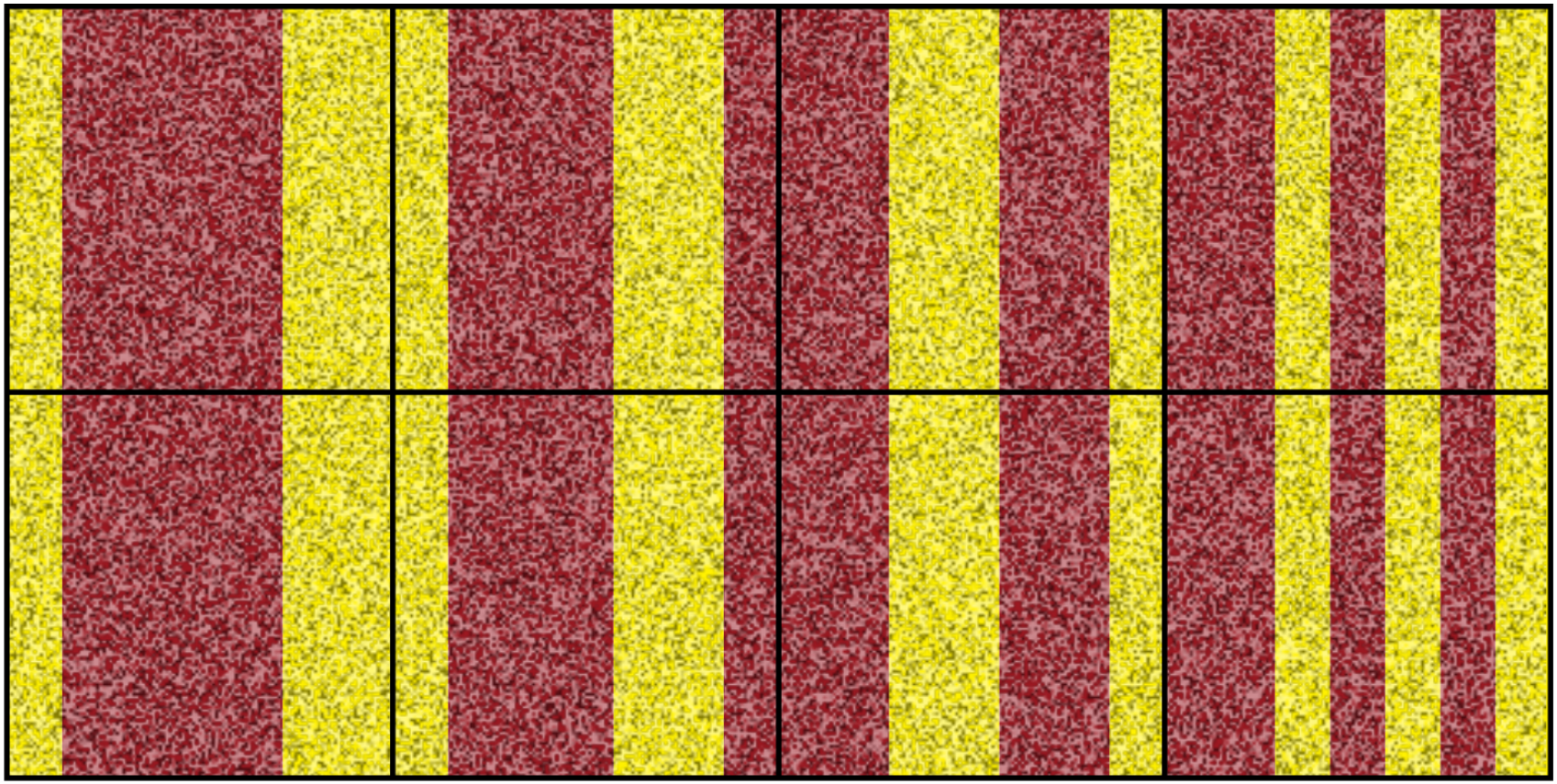
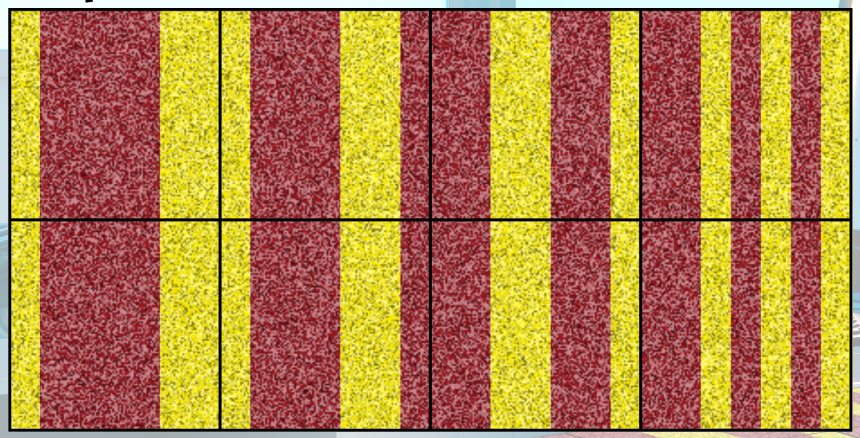


TOY FMRI

TOY FMRI

Input



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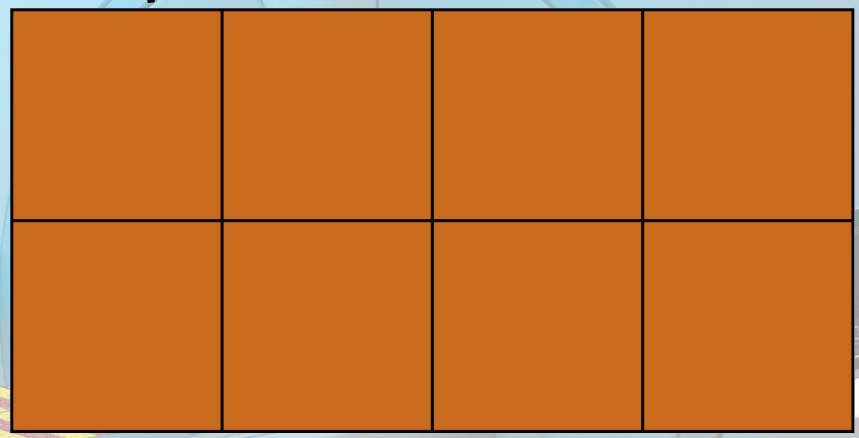

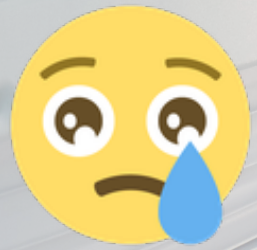

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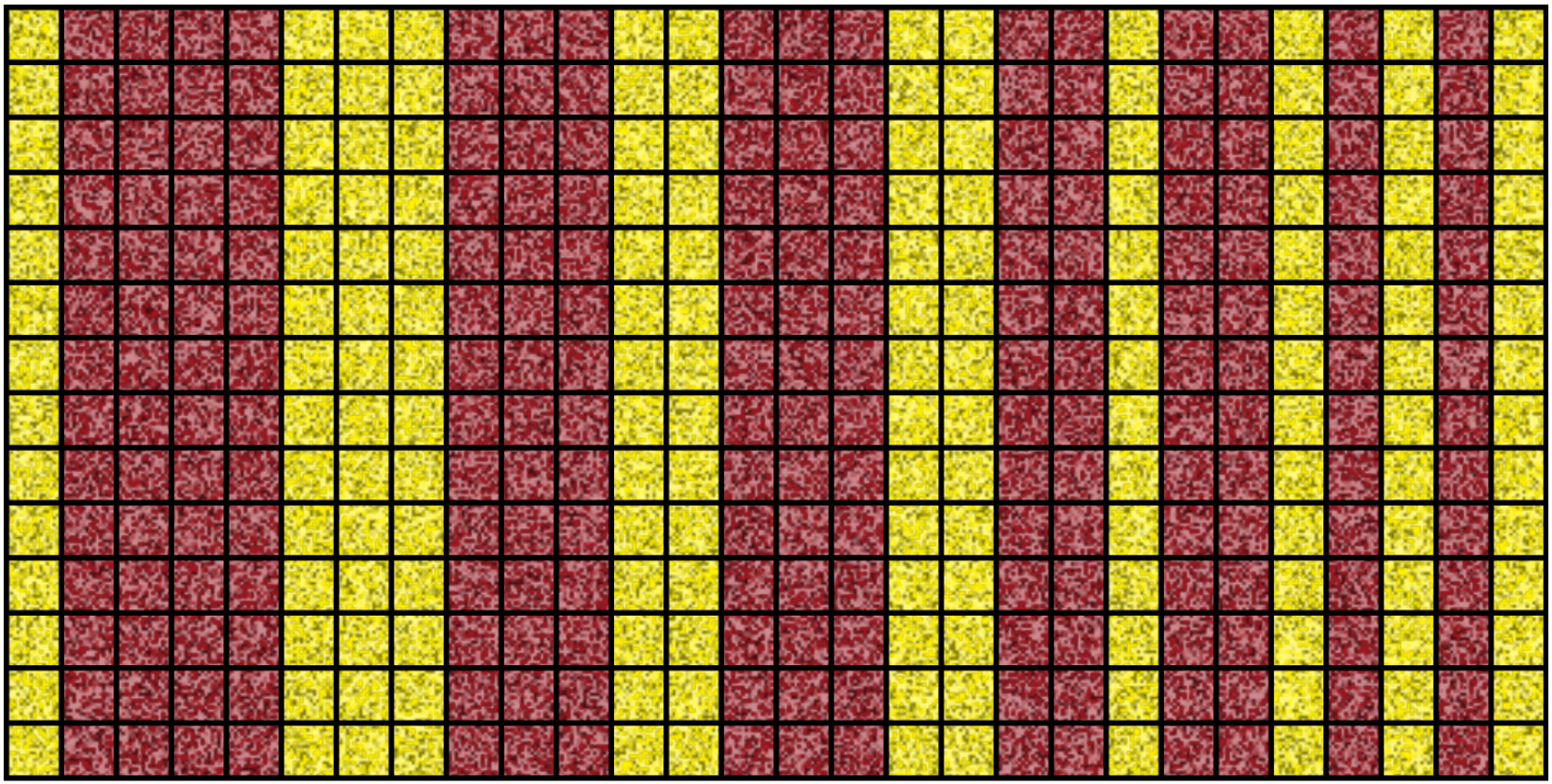
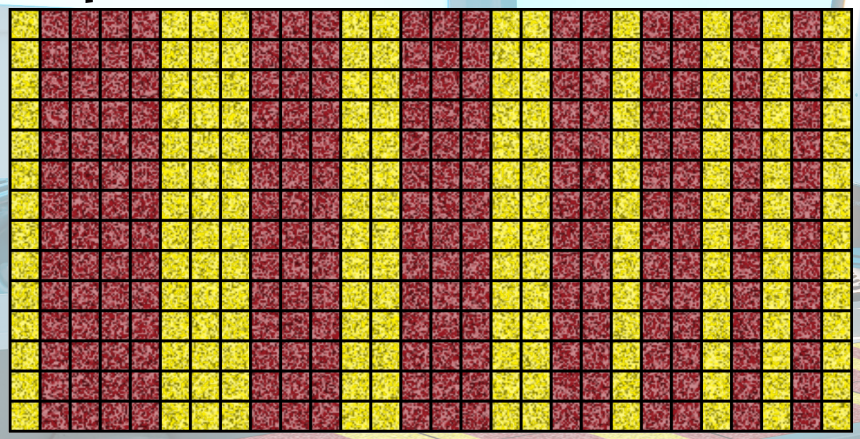


TOY FMRI

TOY FMRI

Input



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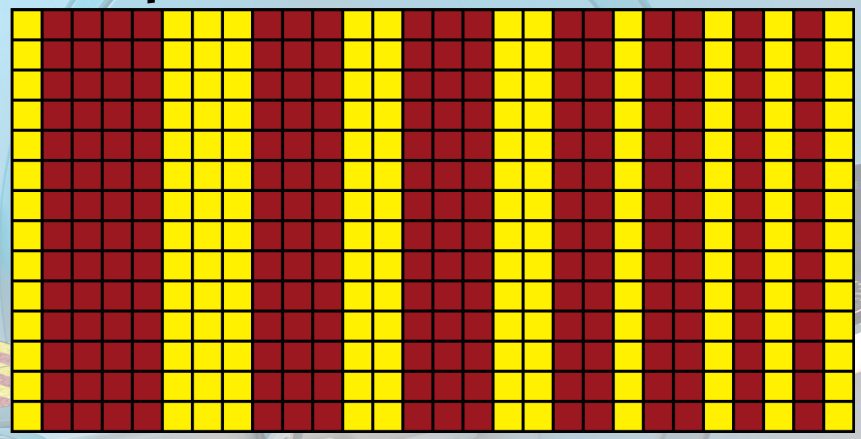


SMOOTHNESSES

- sub-voxel smoothness

SMOOTHNESSES

- sub-voxel smoothness

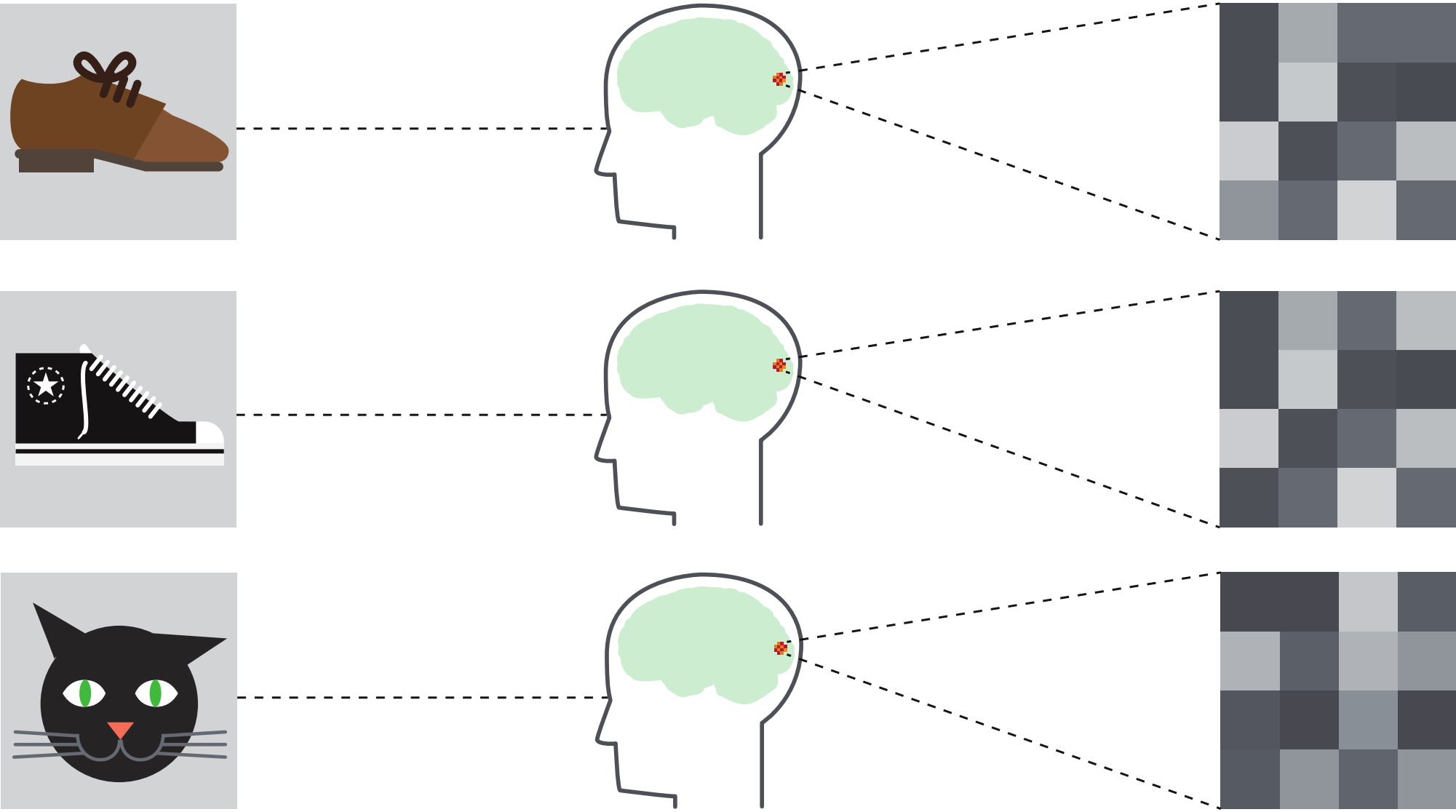
- voxel inhomogeneity

SMOOTHNESSES

- sub-voxel smoothness
- voxel inhomogeneity
- 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

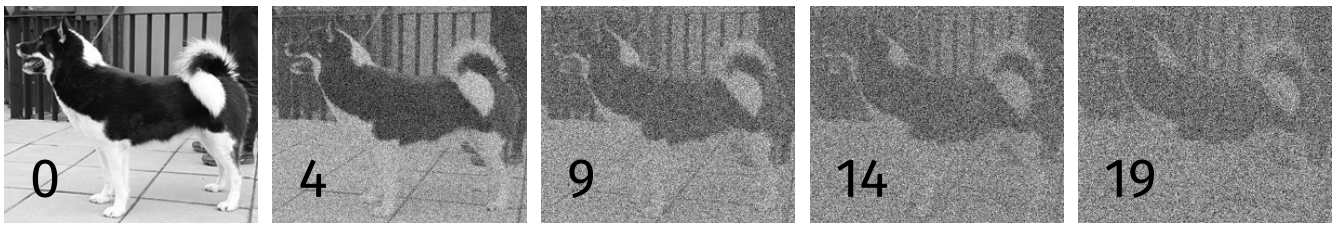
CODES THAT DO NOT WORK

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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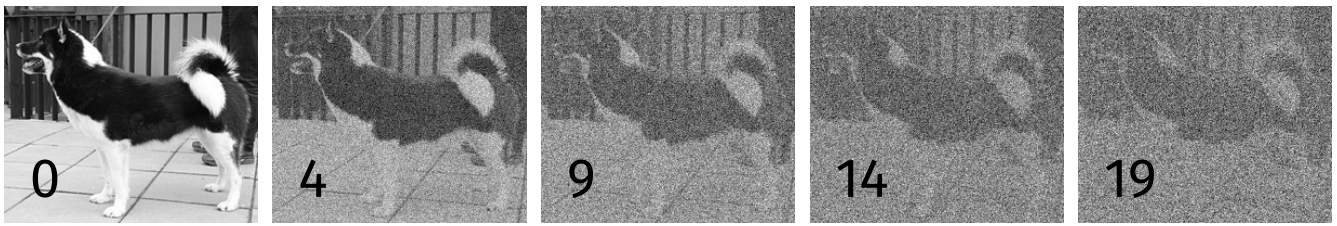
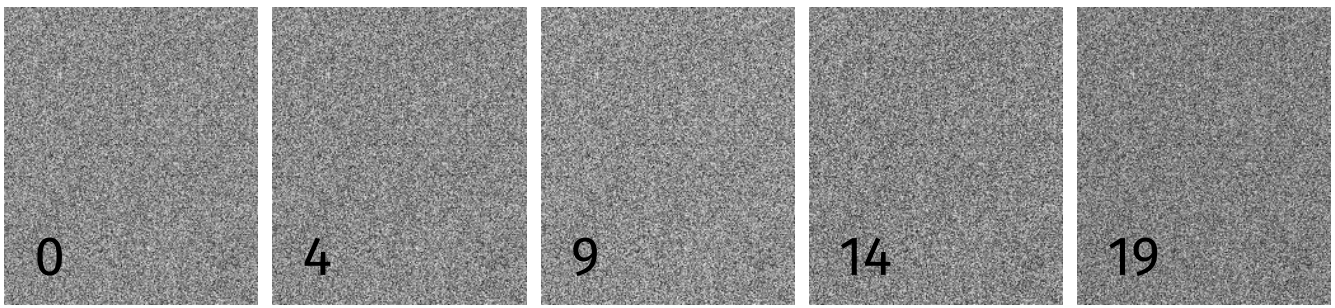




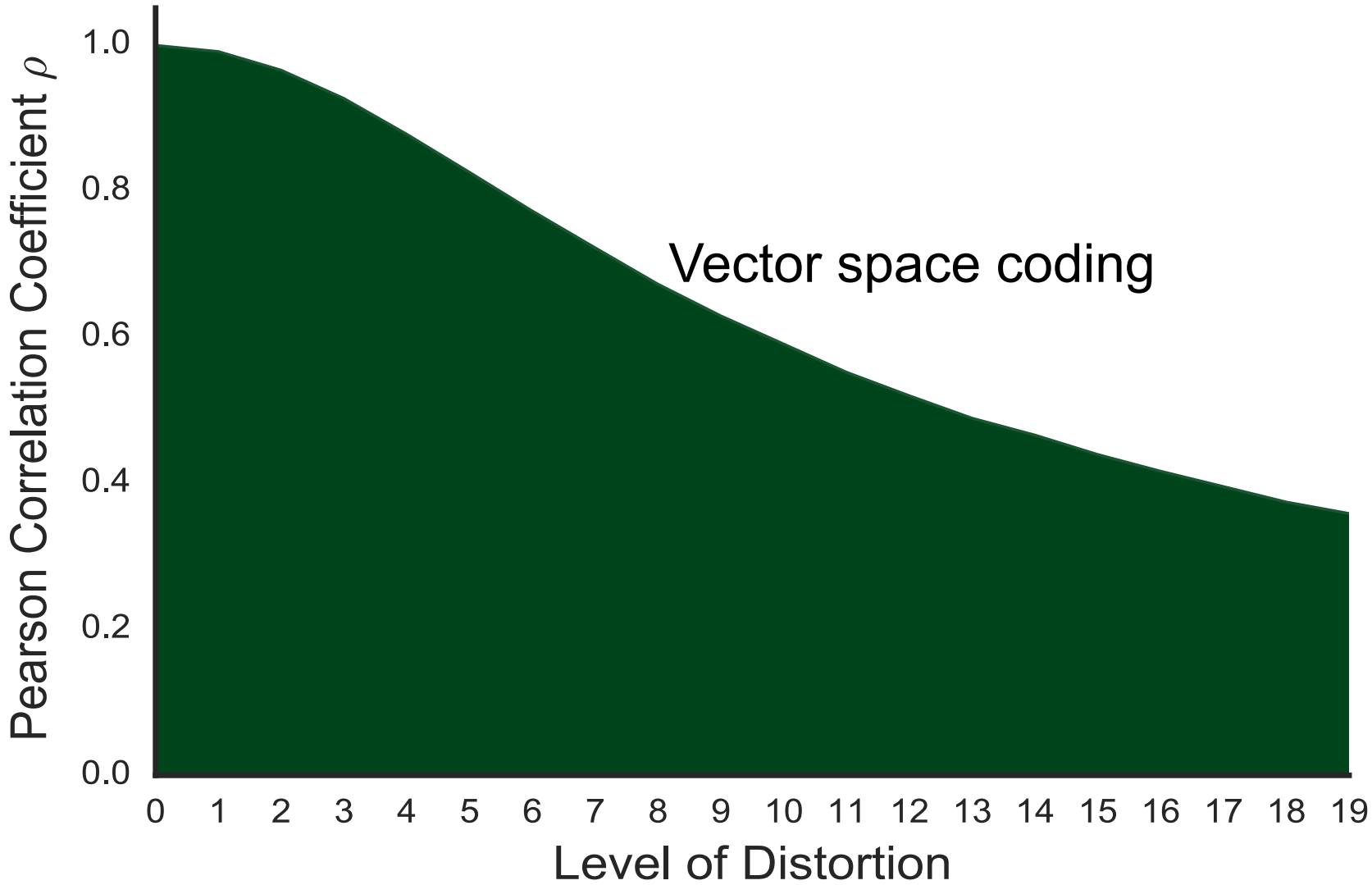
CODES THAT WORK

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

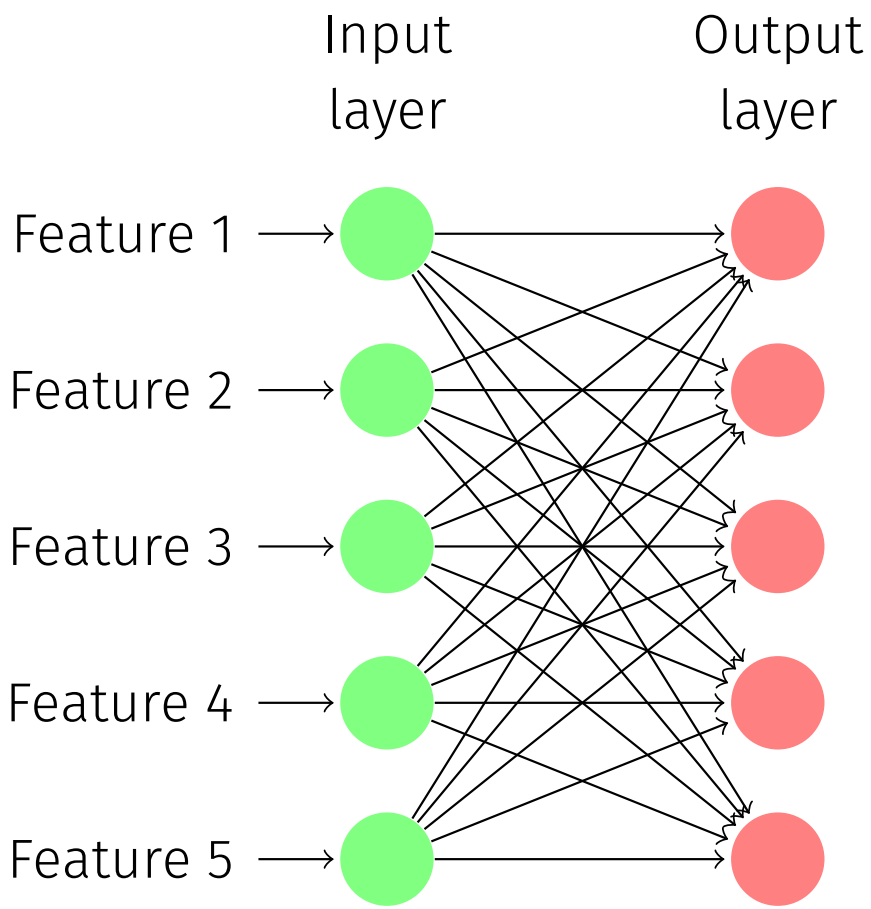
VECTOR SPACE CODING

$$235 \times 200 = 47000$$

VECTOR SPACE CODING

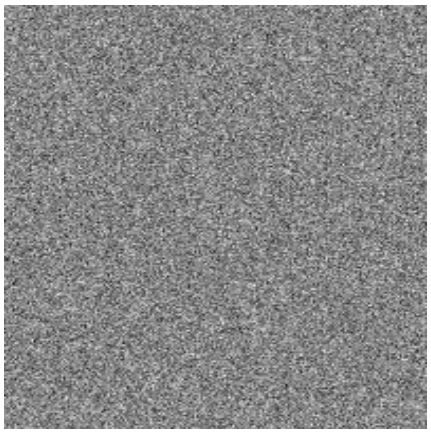


MATRIX MULTIPLICATION CODING



MATRIX MULTIPLICATION CODING

MATRIX MULTIPLICATION CODING



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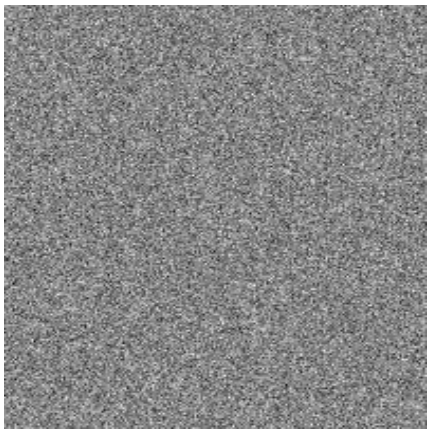
MATRIX MULTIPLICATION CODING



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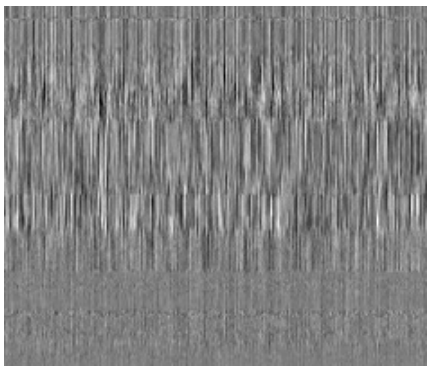

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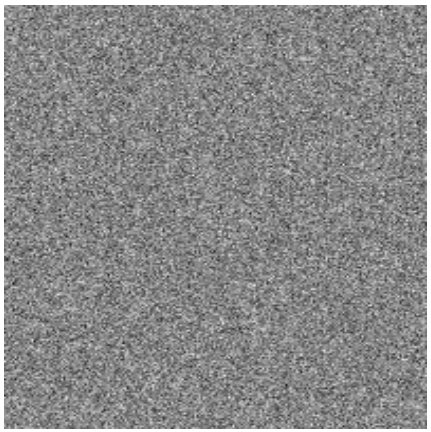

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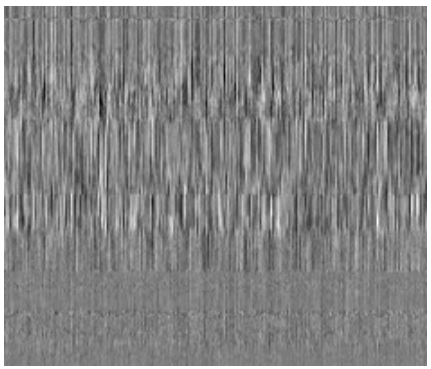
tanh



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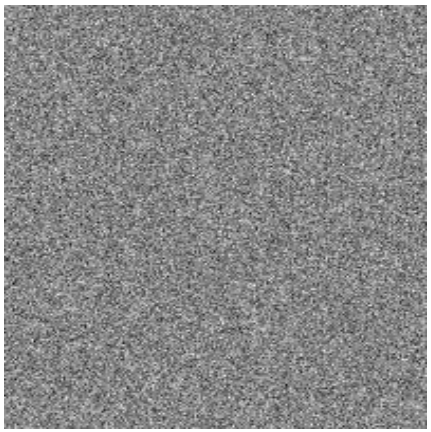

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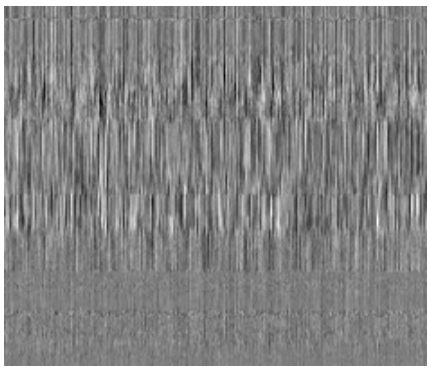
tanh



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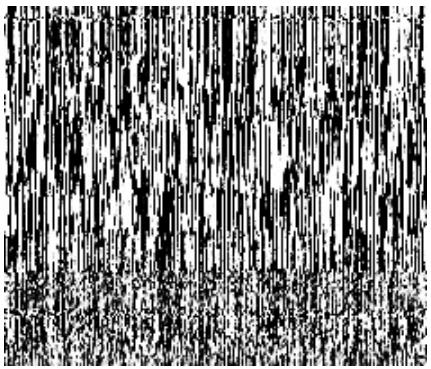
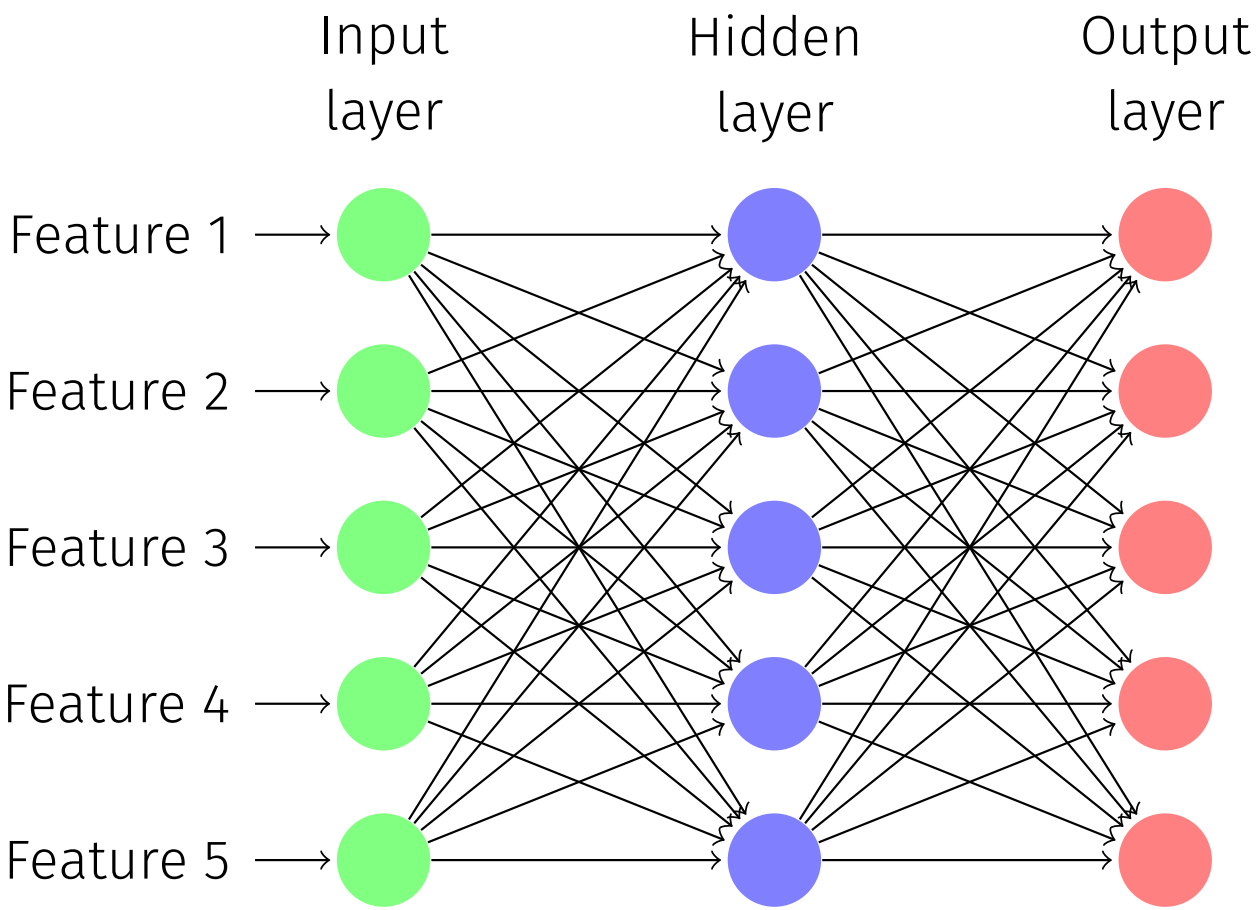
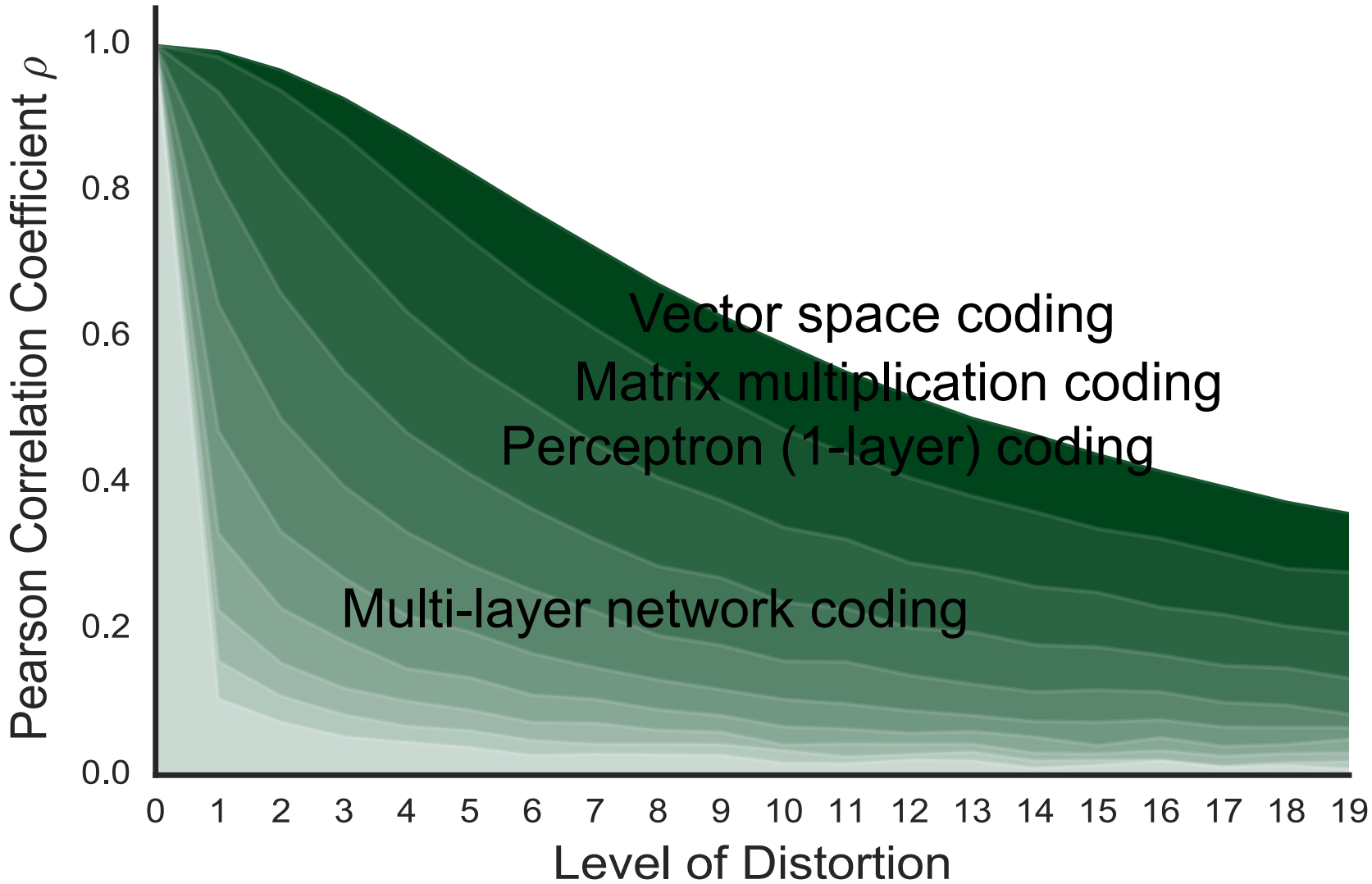


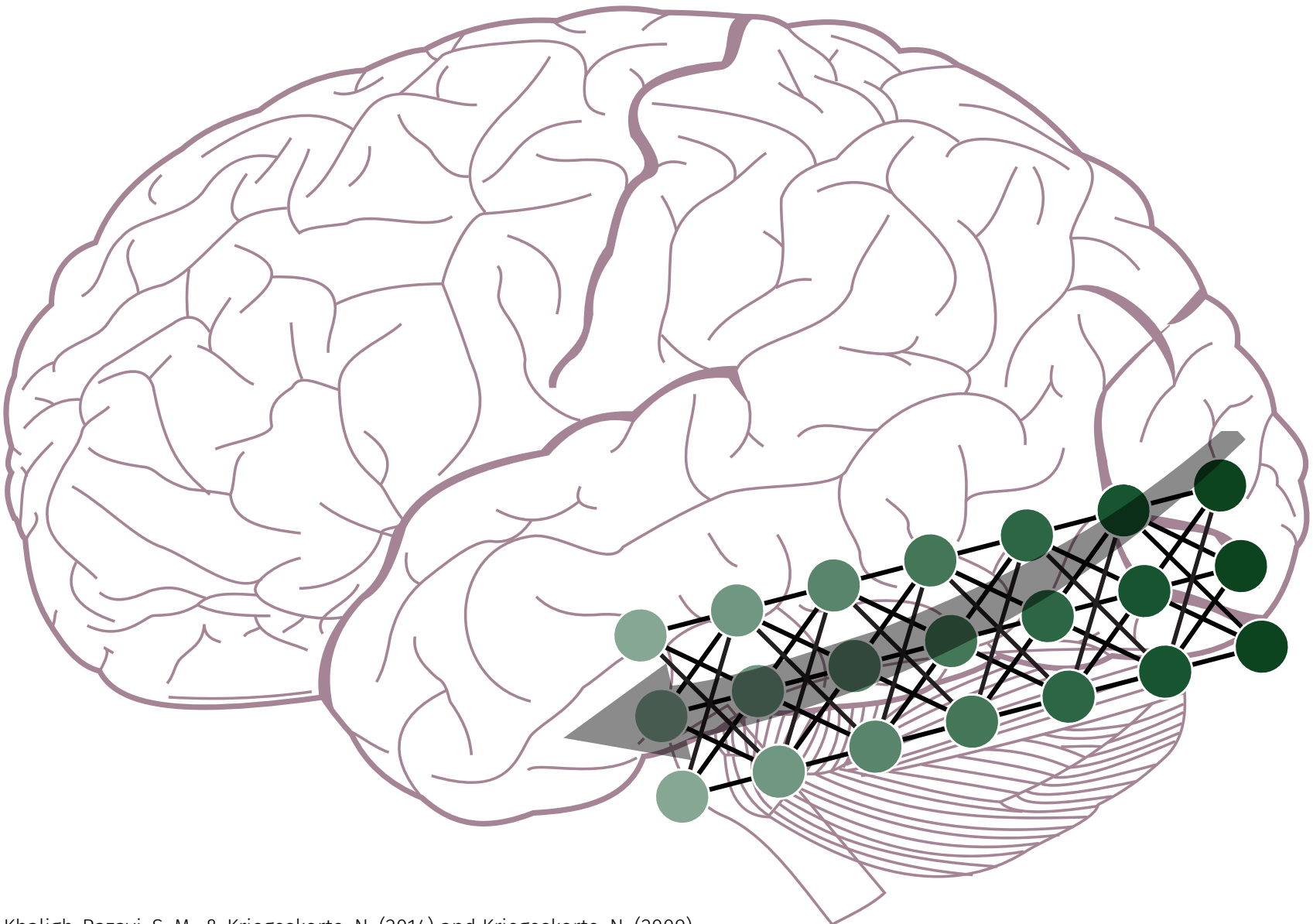
ARTIFICIAL NEURAL NETWORK CODING



DEEP NETWORK CODING

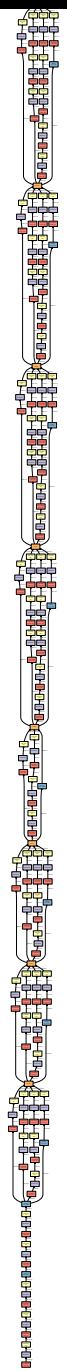


DEEP NETWORK CODING



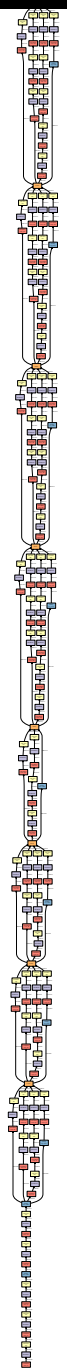
Khaligh-Razavi, S. M., & Kriegeskorte, N. (2014) and Kriegeskorte, N. (2009)

DEEP NETWORK CODING



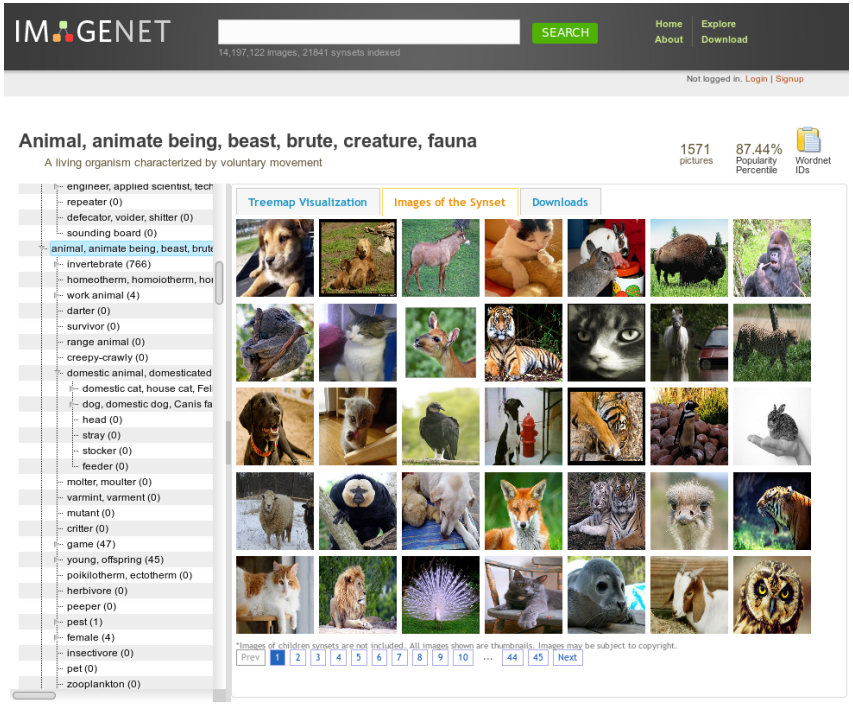
DEEP NETWORK CODING

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

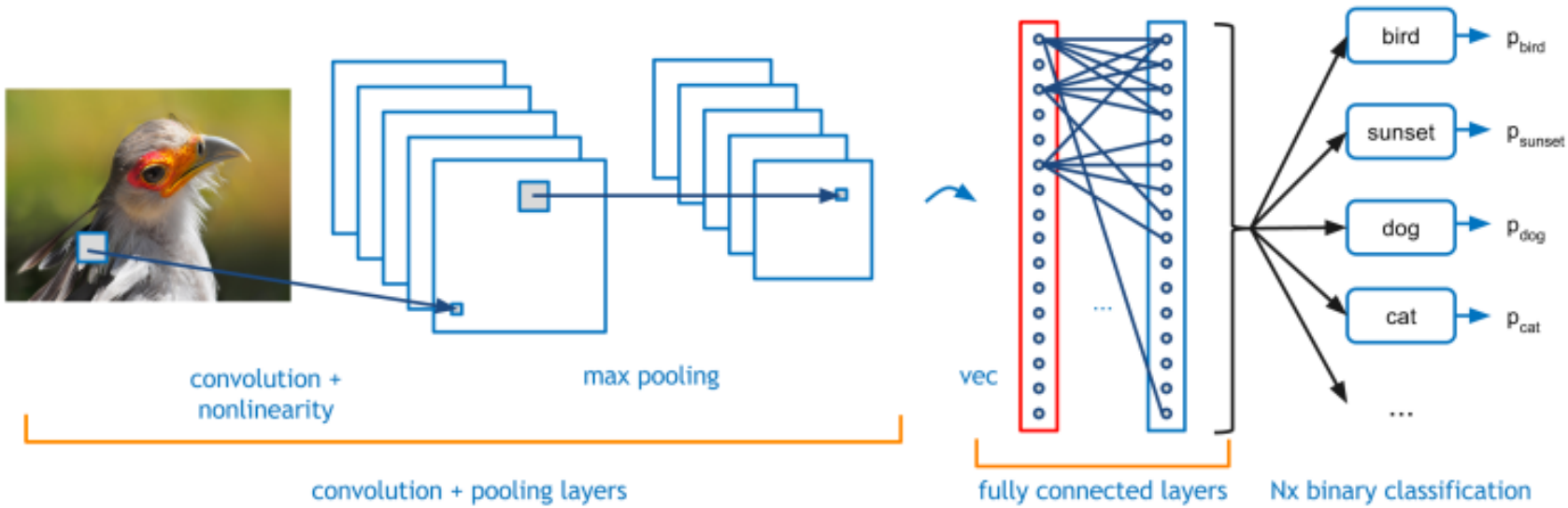


DEEP NETWORK CODING

- trained on millions of photos
- 1000 categories



DEEP NETWORK CODING



DEEP NETWORK CODING

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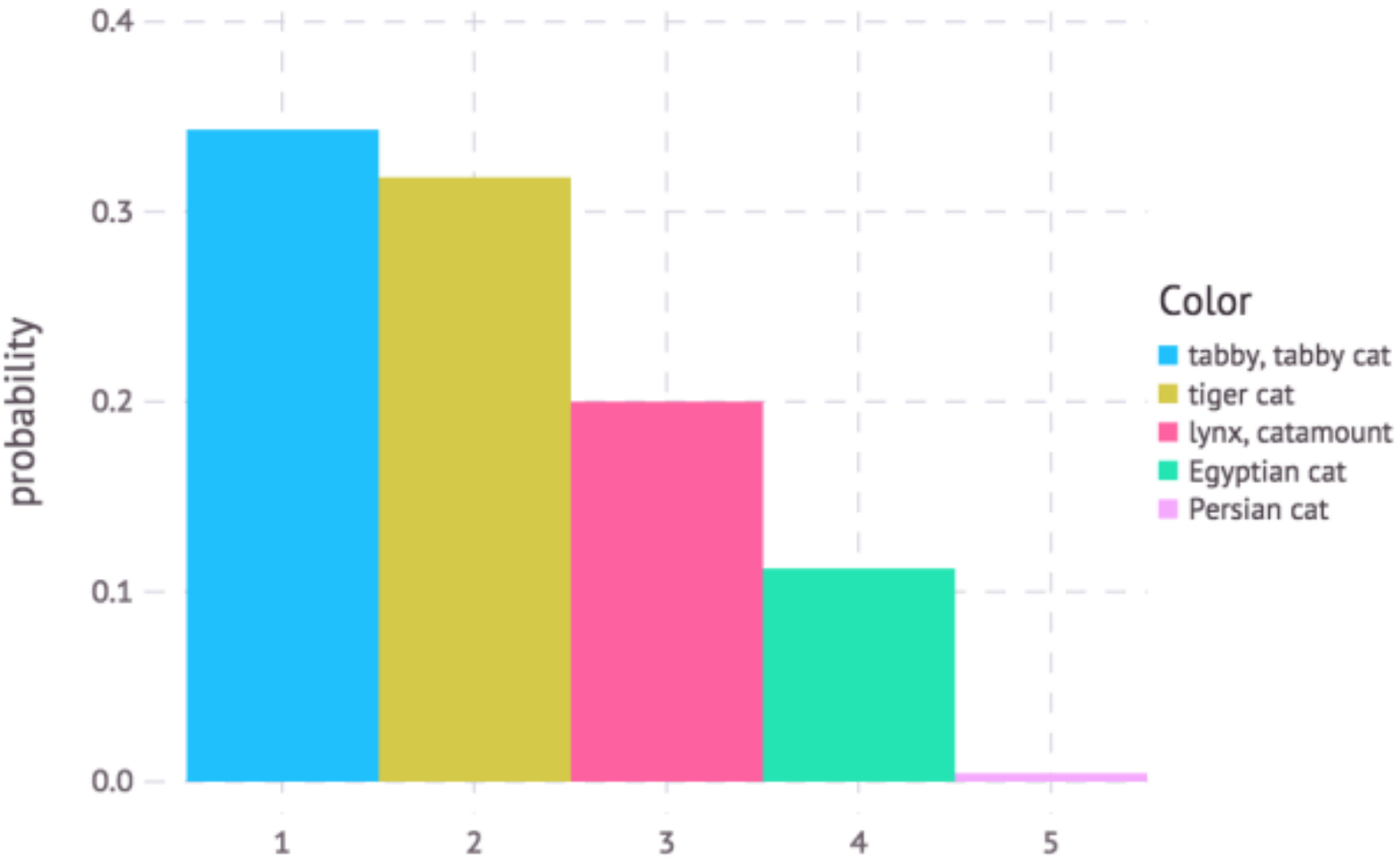

DEEP NETWORK CODING

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

DEEP NETWORK CODING

- dust cover: 44.9%
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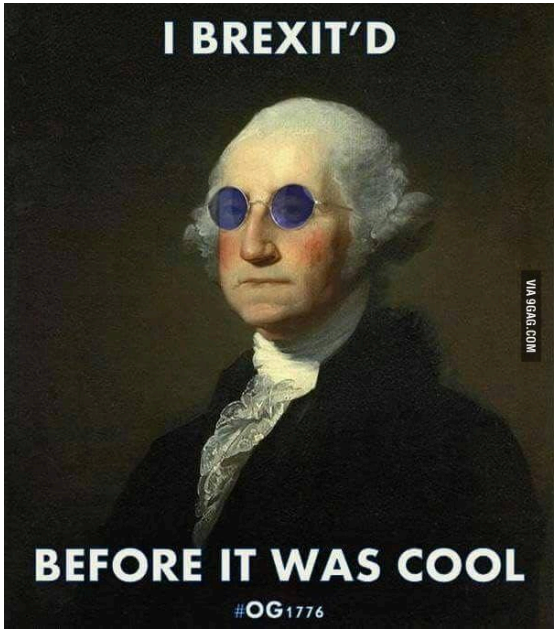
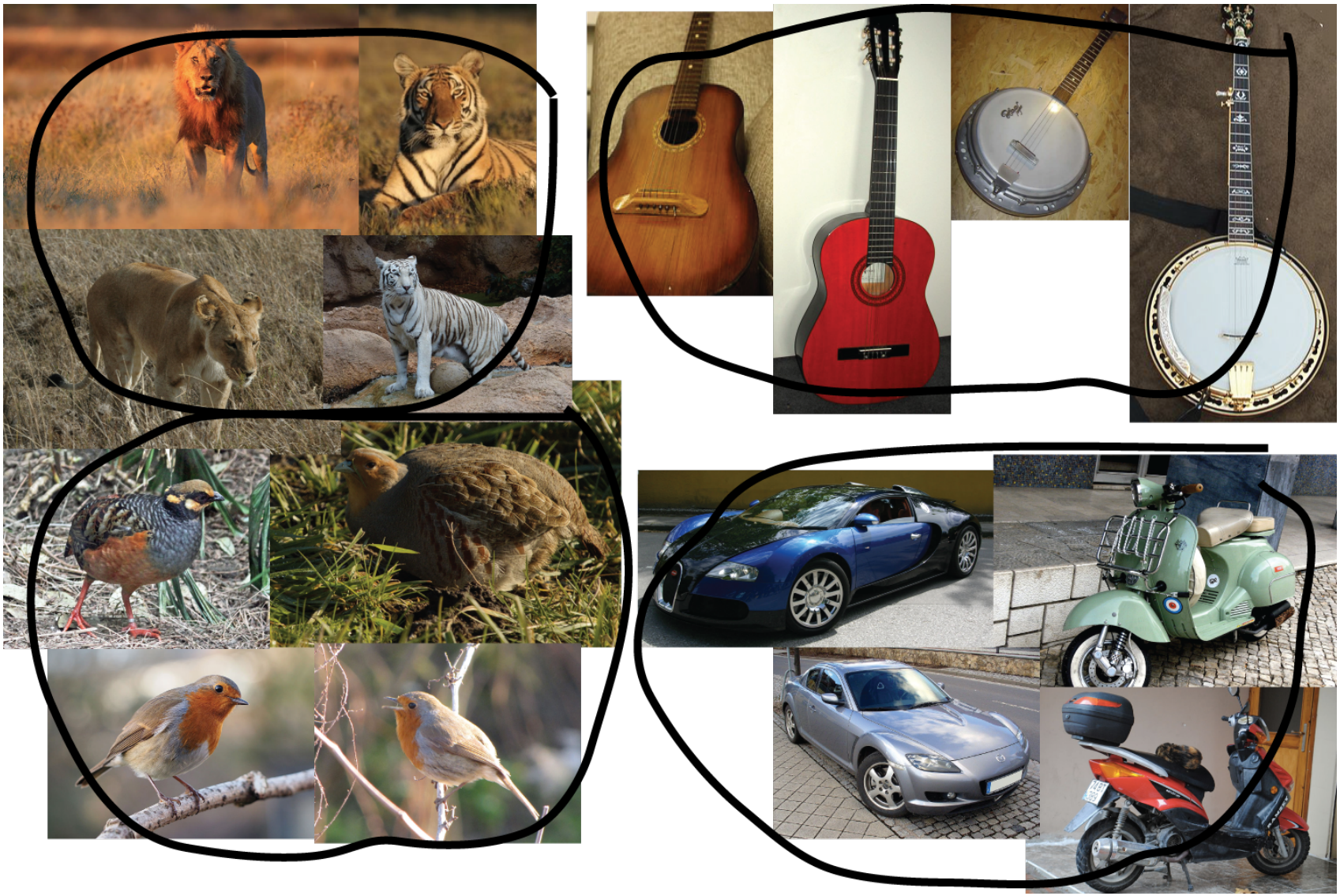


- sunglasses: 40.7%
- wig: 8.4%
- sunglass: 7.9%
- dust cover: 5.6%
- suit: 2.8%

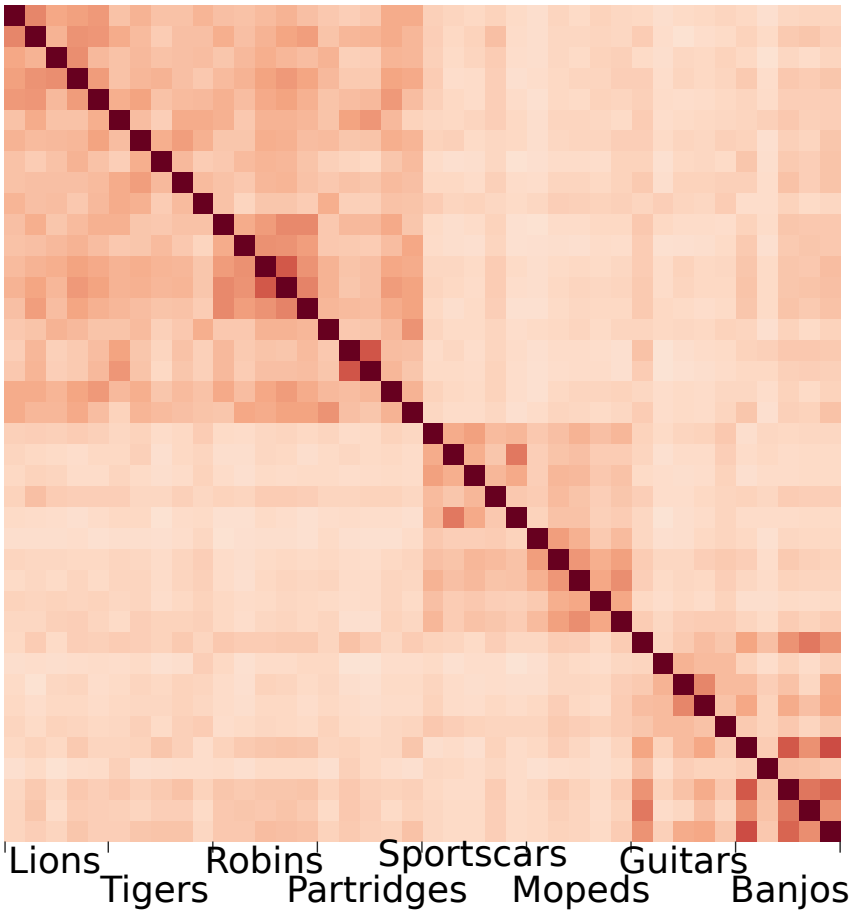
DEEP NETWORK CODING

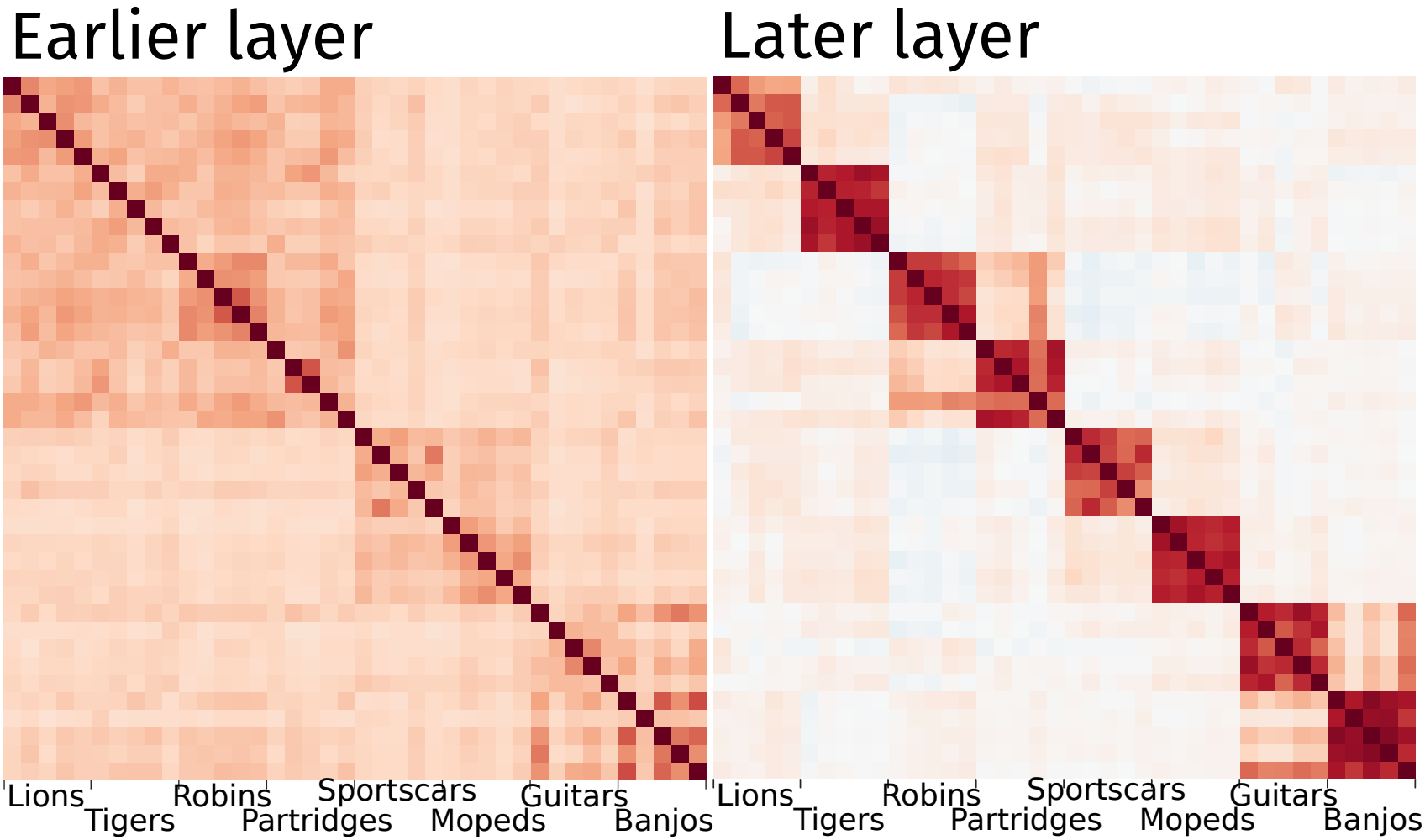
DEEP NETWORK CODING



DEEP NETWORK CODING

Earlier layer




Earlier layer
Later layer
Lions
Tigers
Robins
Partridges
Sportscars
Mopeds
Guitars
Banjos
Lions
Tigers
Robins
Partridges
Sportscars
Mopeds
Guitars
Banjos

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%