



Reconstructing visual and subjective experience from the brain

Yuki Kamitani

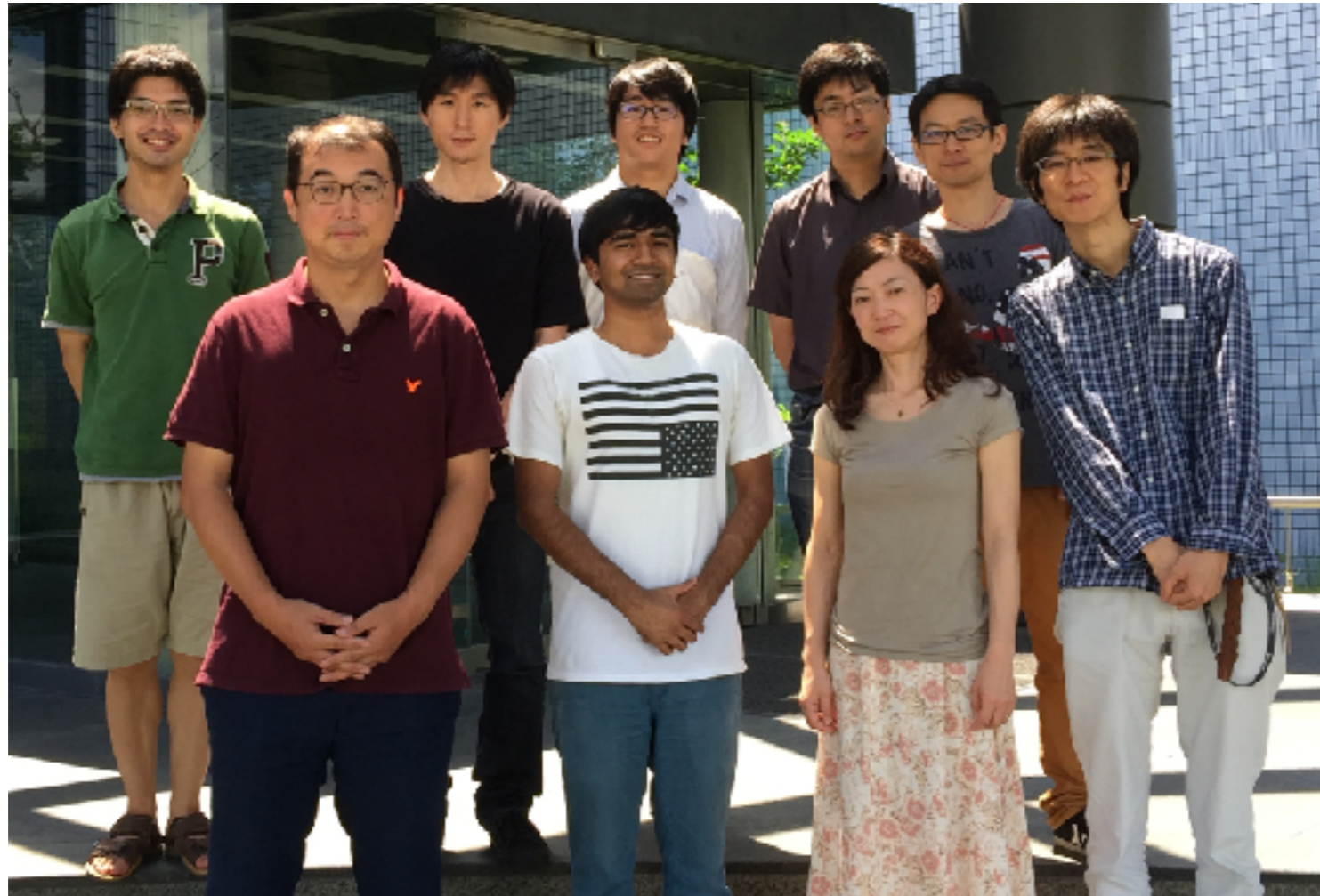
Kyoto University & ATR

<http://kamitani-lab.ist.i.kyoto-u.ac.jp>



@ykamit

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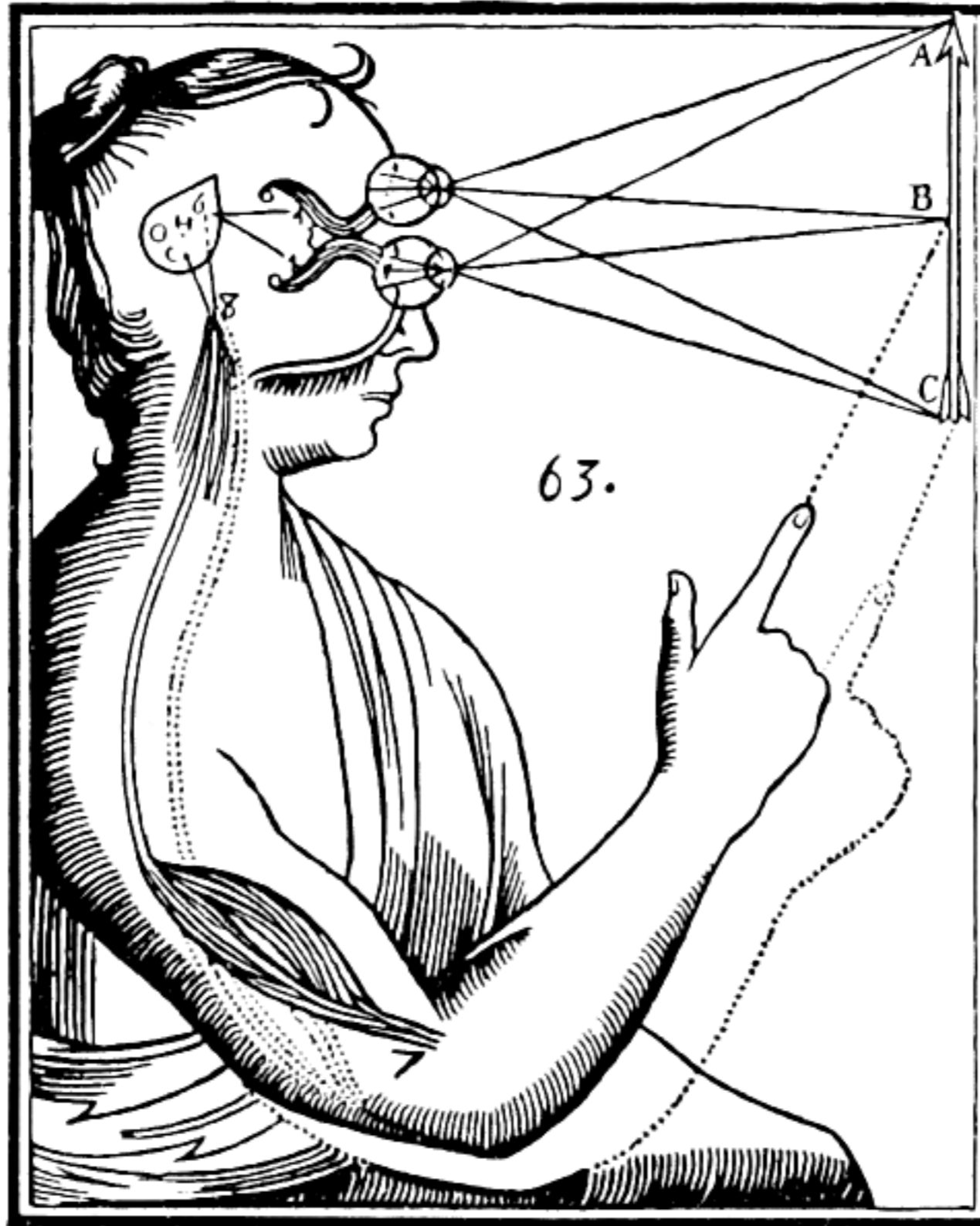
<http://kamitani-lab.ist.i.kyoto-u.ac.jp>

Github: <https://github.com/KamitaniLab>

 @ykamit

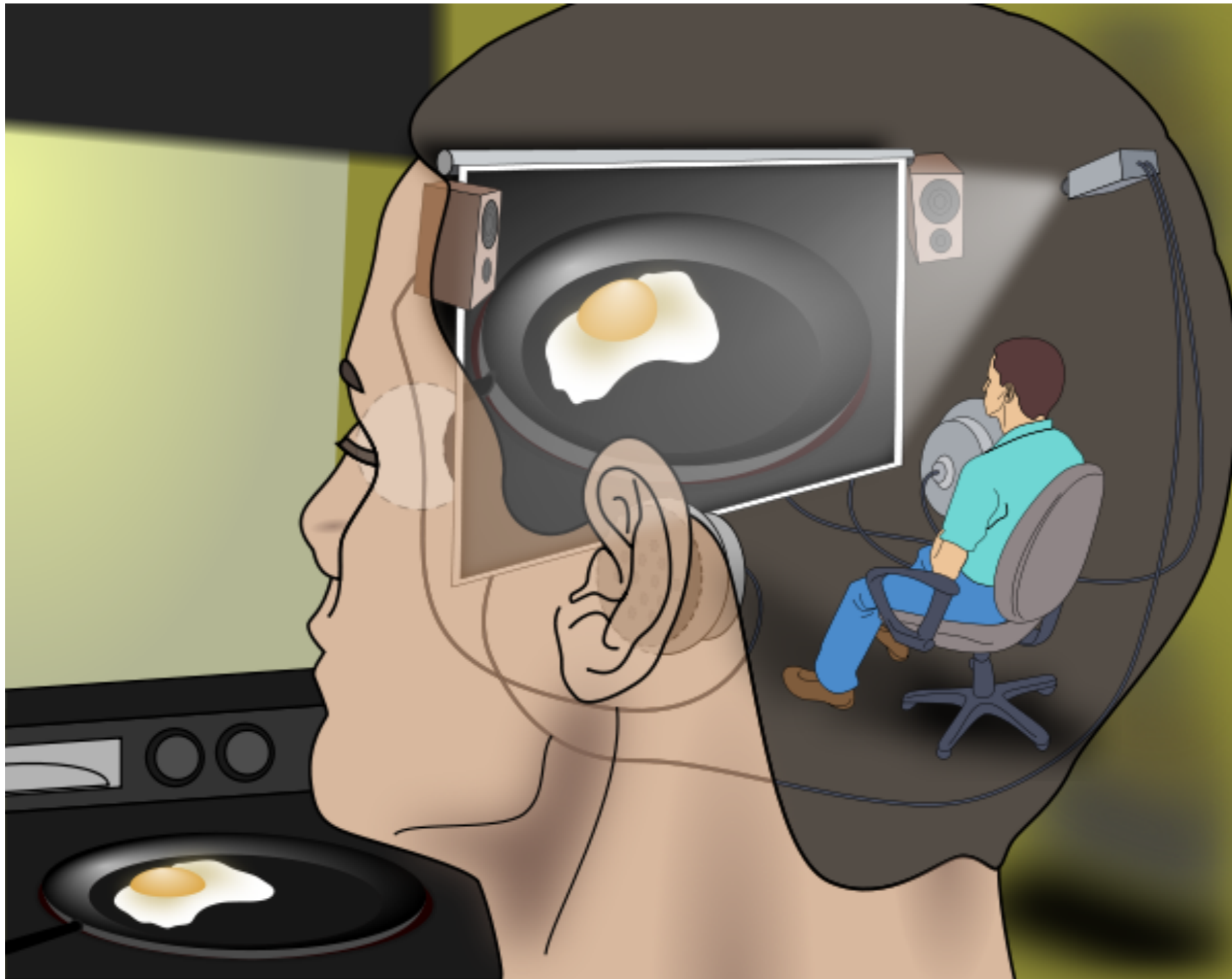
Grants

JSPS KAKENHI Grant number 26870935, 15H05920, 15H05710, JP20H05705,
JST CREST Grant Number JPMJCR18A5
NEDO (JPNP20006)



Descartes (1677) Treatise on Man

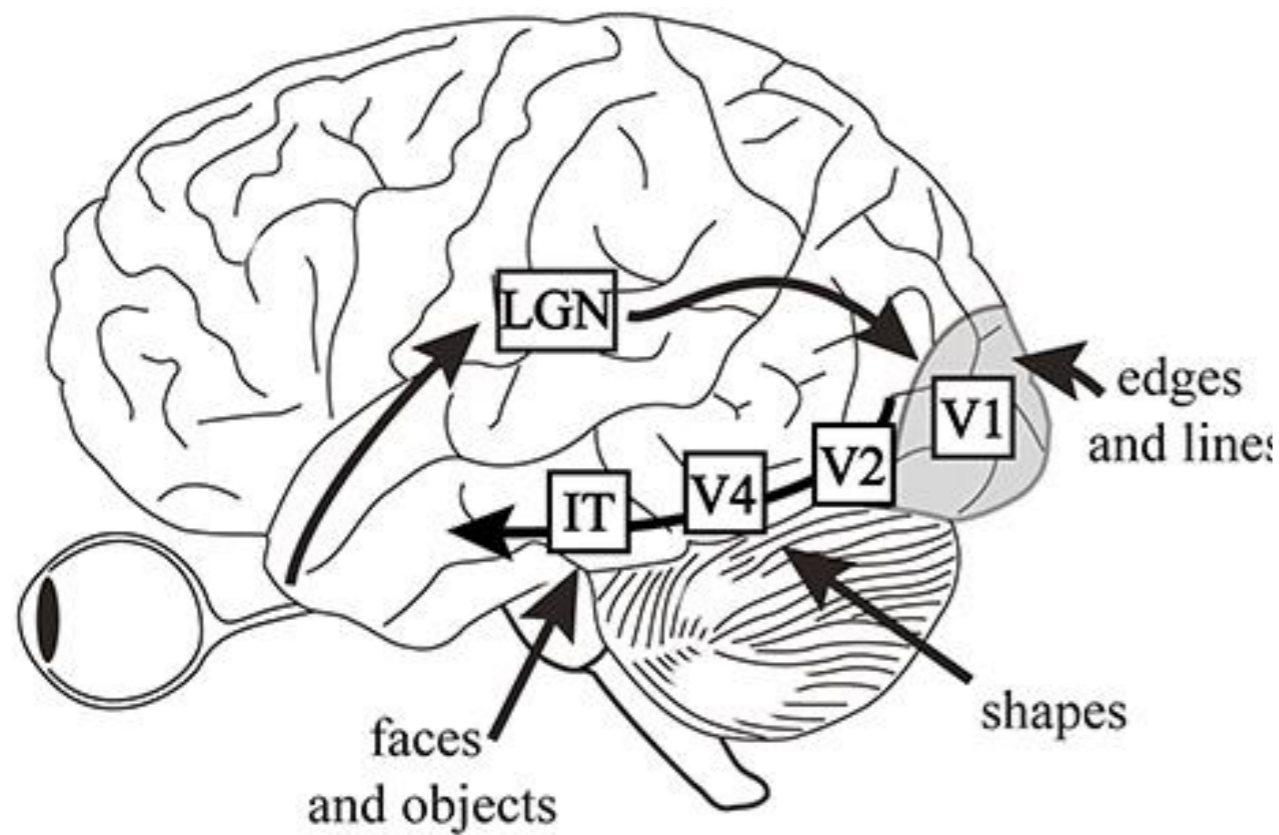
https://en.wikipedia.org/wiki/Mind%E2%80%93body_dualism#/media/File:Descartes_mind_and_body.gif



































“Cartesian Theater”

Dennett (1991) *Consciousness Explained*

https://en.wikipedia.org/wiki/Cartesian_theater



Critical features for neurons in each area

V2	V4	pIT	aIT
 	 	 	 
 	 	 	 
 	 	 	 
 	 	 	 

Kobatake & Tanaka, 1994

Distributed and hierarchical processing:
Reduction to visual features

How to study internal images as a whole?

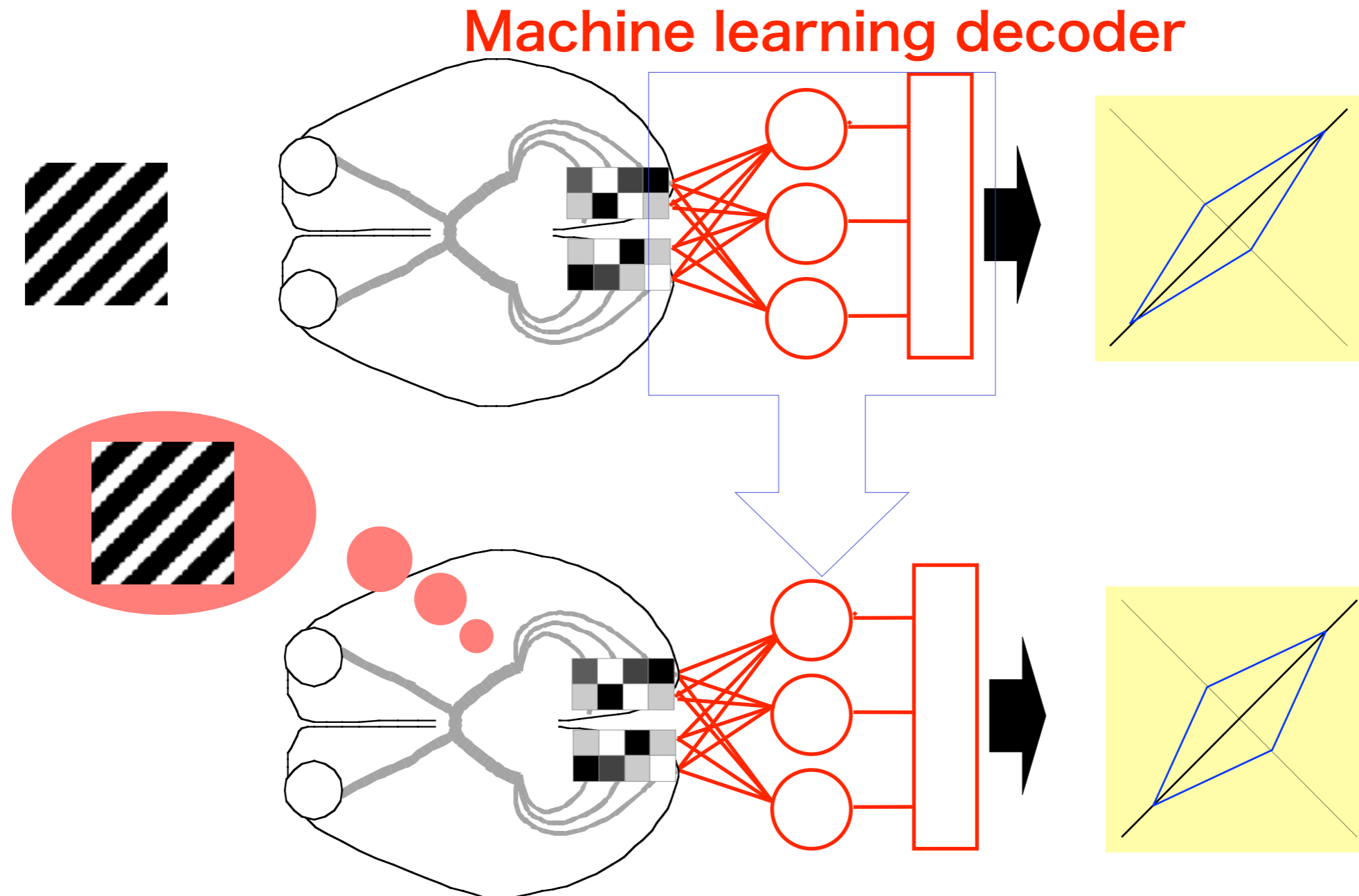
- Introspection
- Verbal report
- Psychopysics
- ***Image reconstruction from brain activity***

Reconstruction:

Synthesizing an image that evokes equivalent brain activity
based on brain decoding

Brain decoding and neural mind-reading

(Kamitani & Tong, *Nature Neuroscience* 2005)

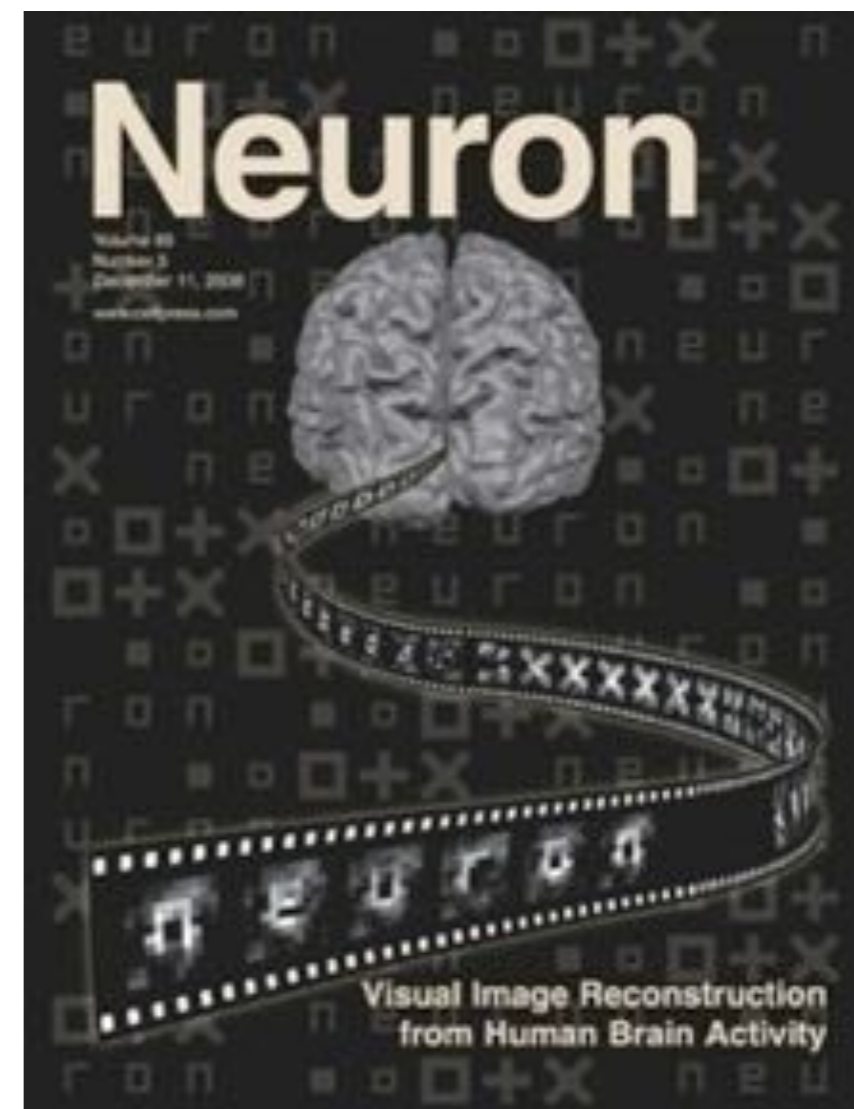
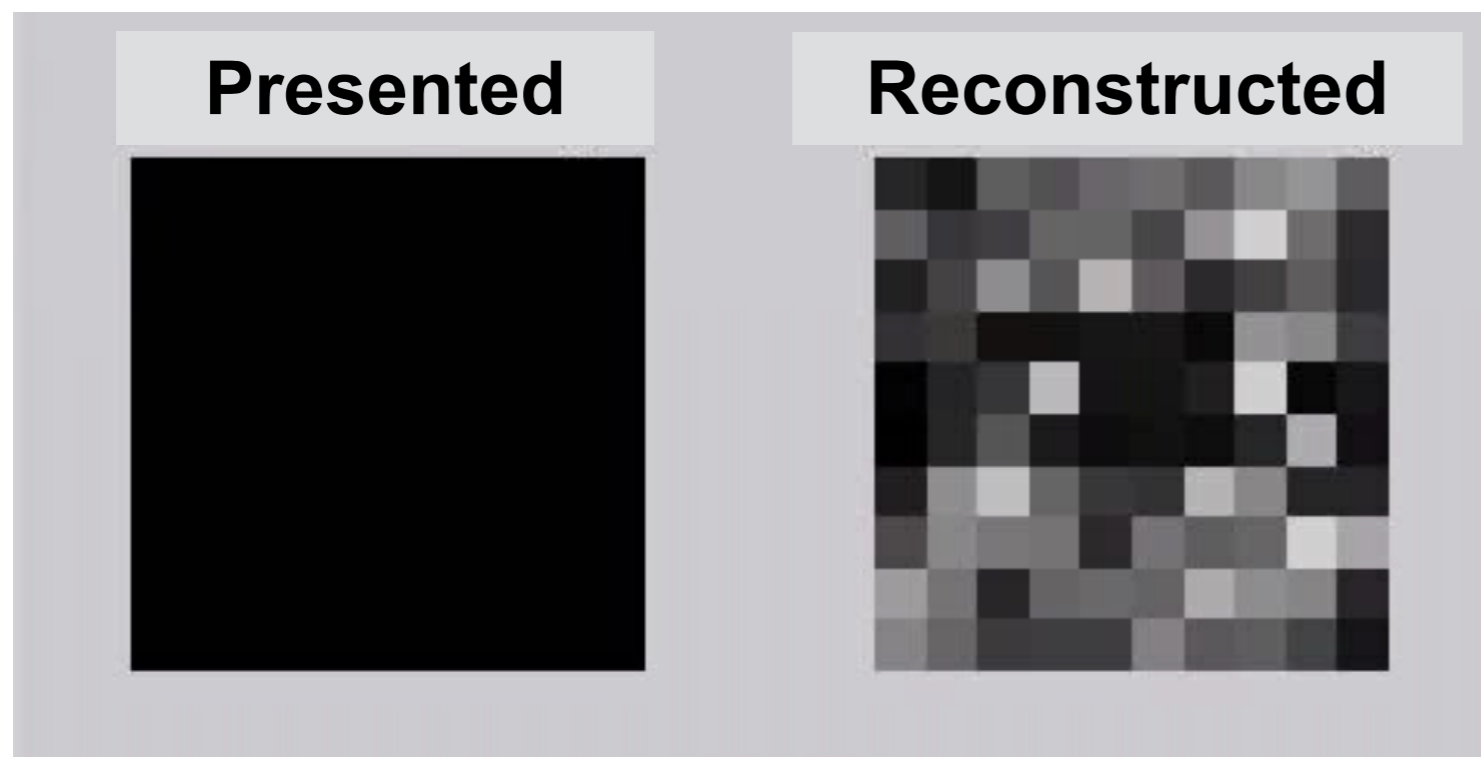
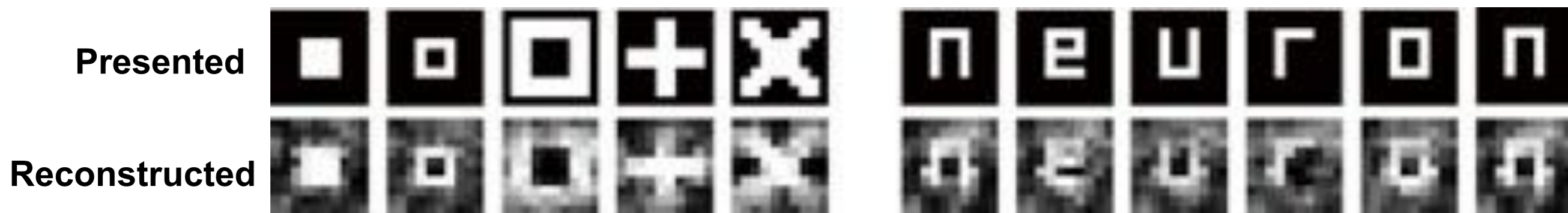


Transfer of machine learning decoders:

Train - Stimulus-induced, unambiguous

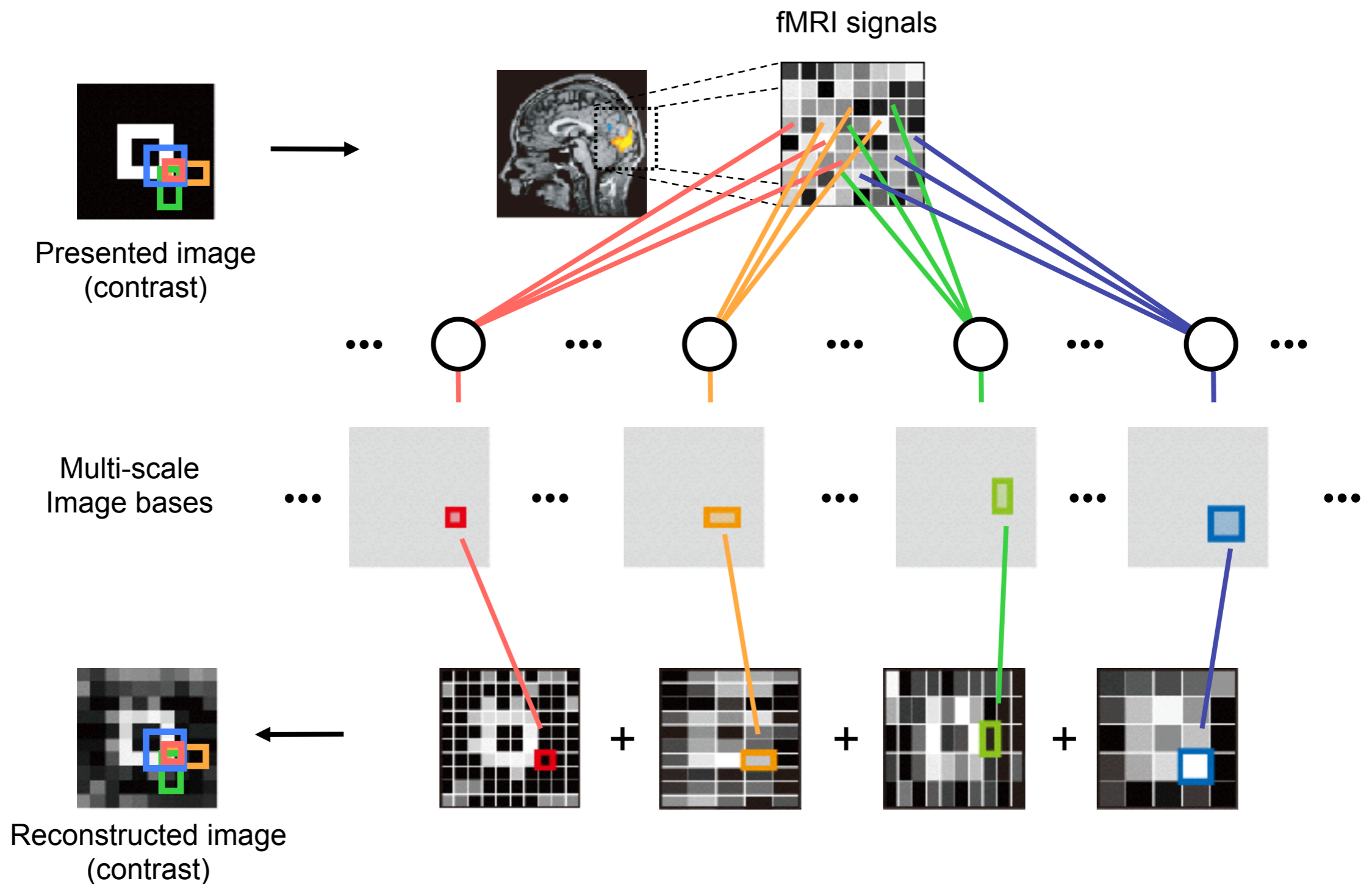
Test - Subjective (imagery, dreaming, etc)

Visual image reconstruction



(Miyawaki, Uchida, Yamashita, Sato, Morito, Tanabe, Sadato, Kamitani, *Neuron* 2008)

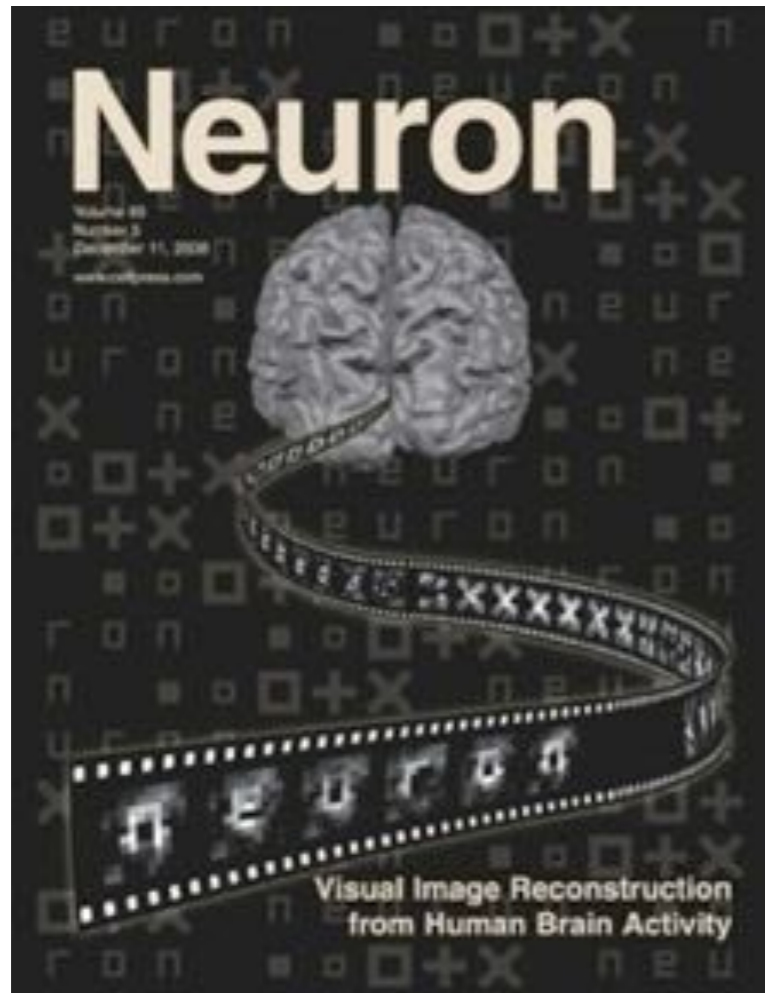
Modular decoding with local contrast features (bases)



Training: ~400 random images

Test: Images not used in training (arbitrary images; 2^{100})

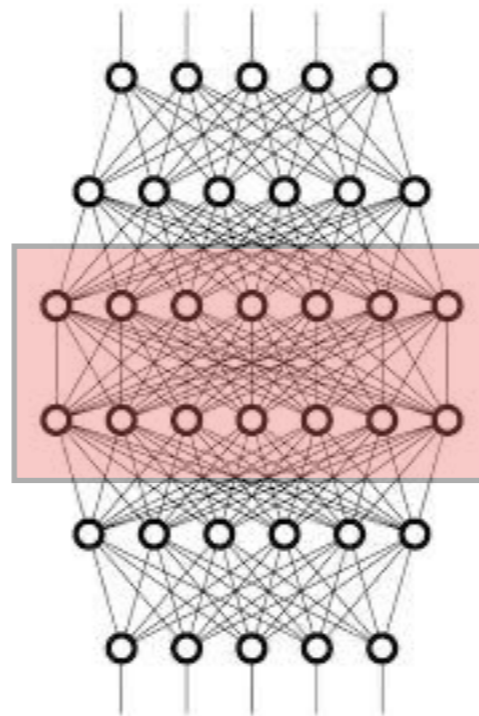
Between low and high?



Visual image reconstruction
by decoding *local contrasts*

(*Neuron*, 2008)

DNN

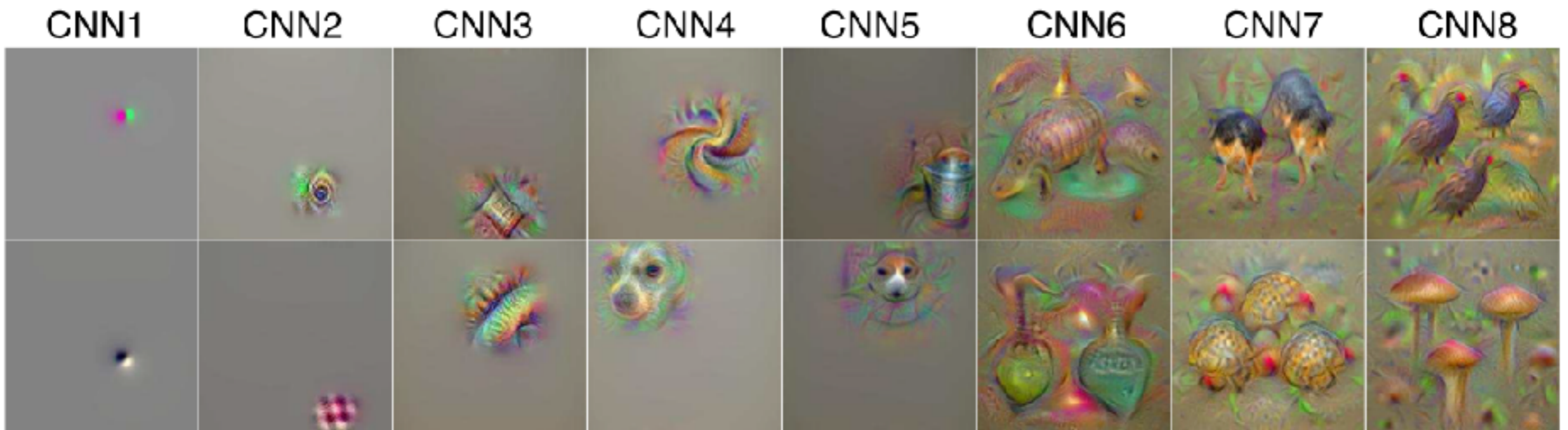


Decoding dream contents
by decoding *semantic categories*

(*Science*, 2013)

































Hierarchical representations in DNN and the brain

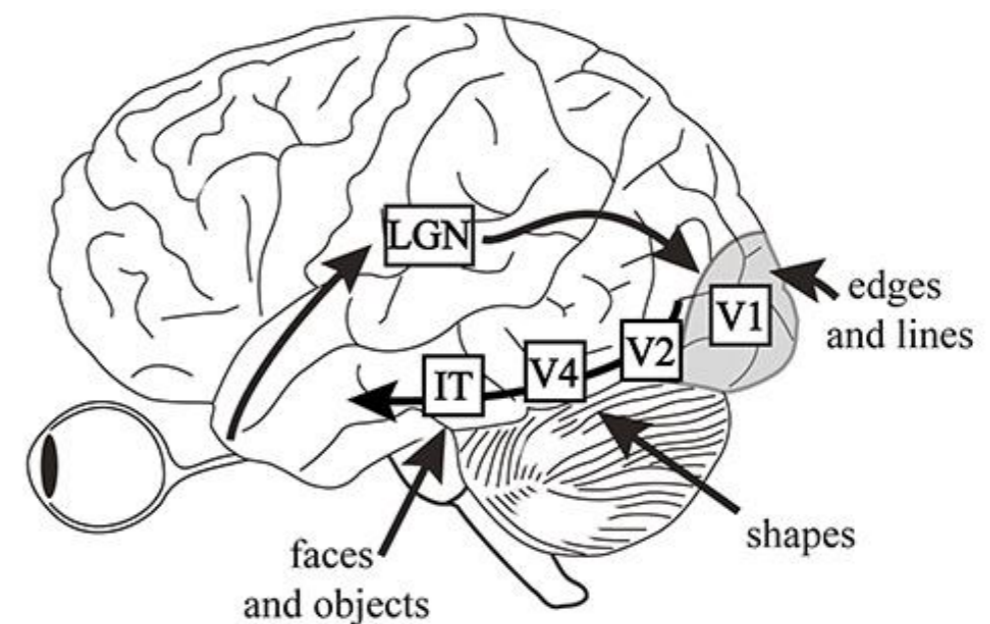
Preferred image computed for each CNN unit



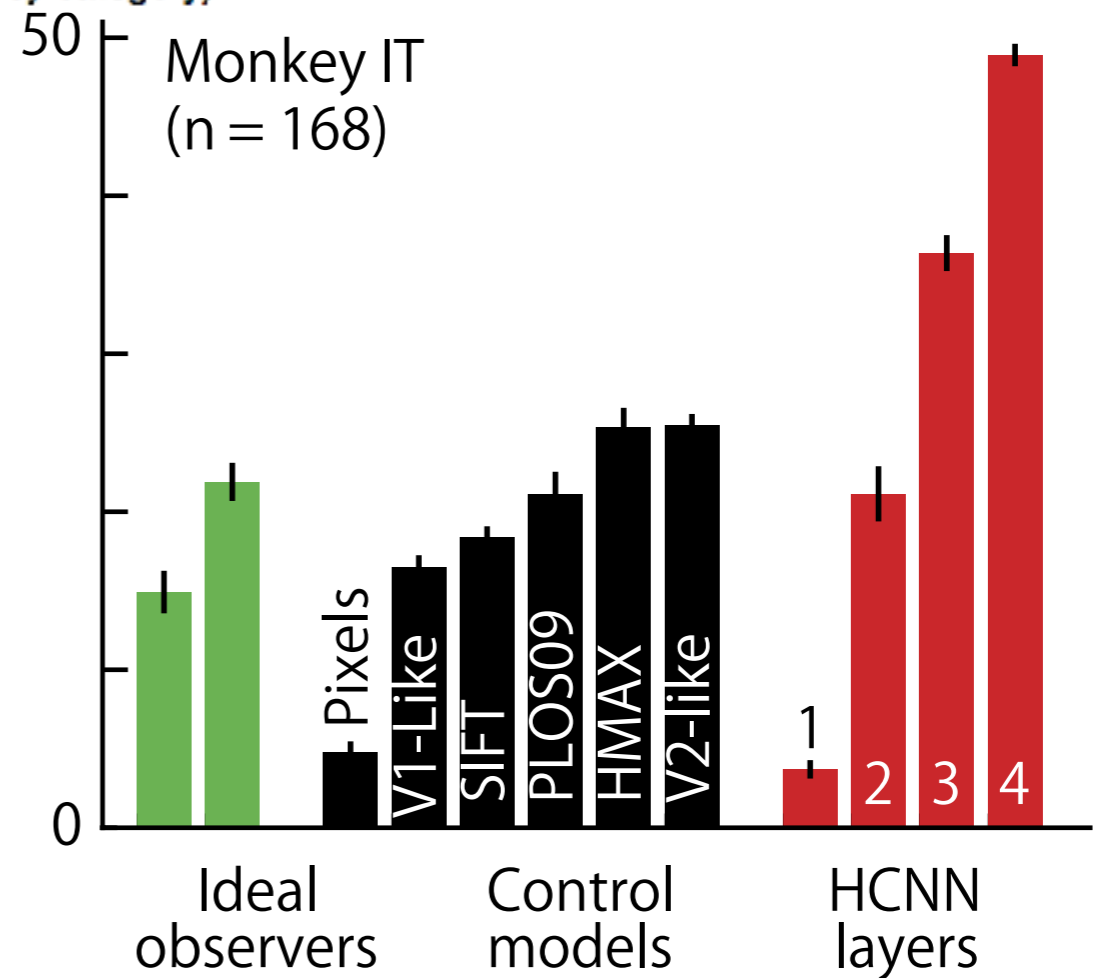
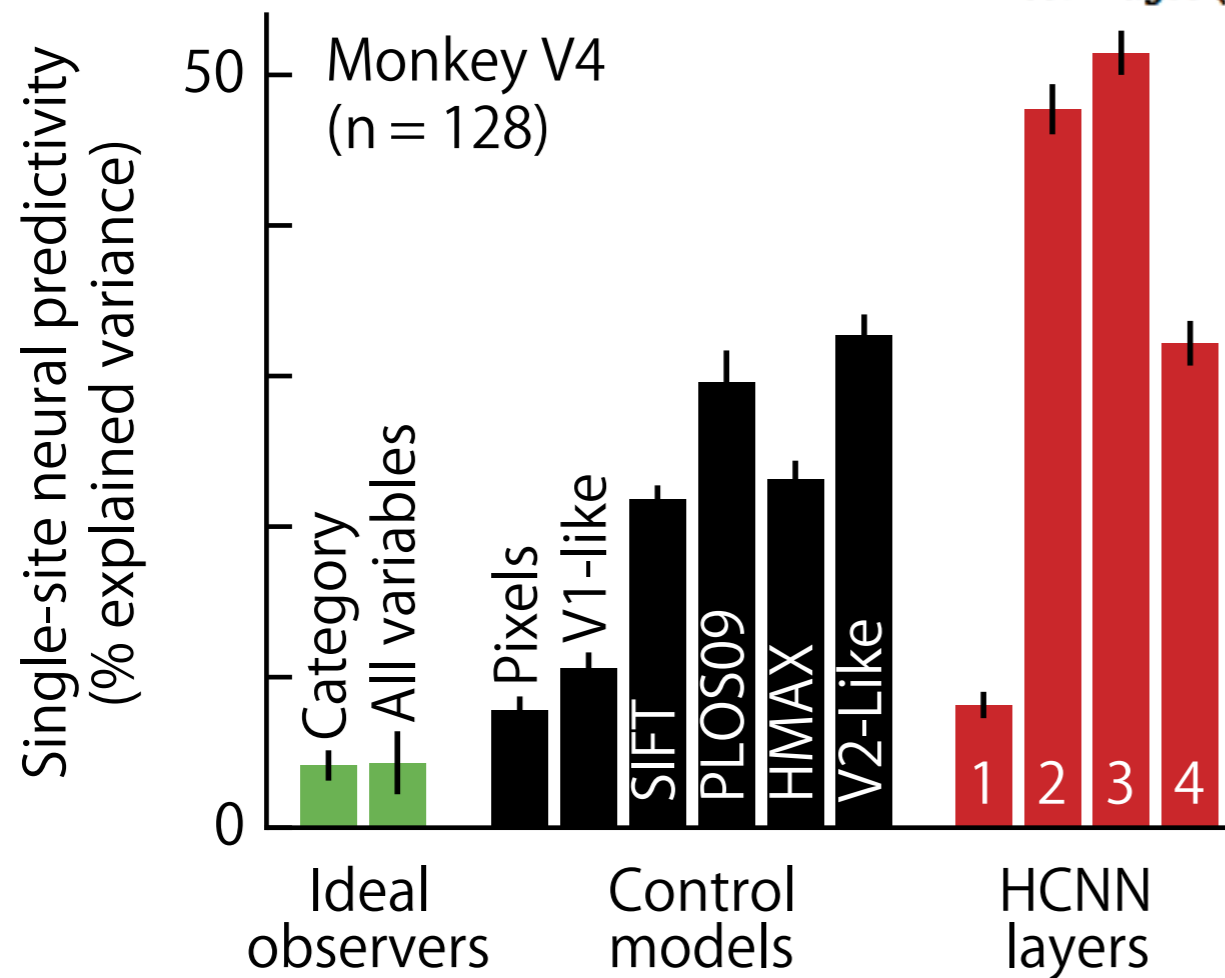
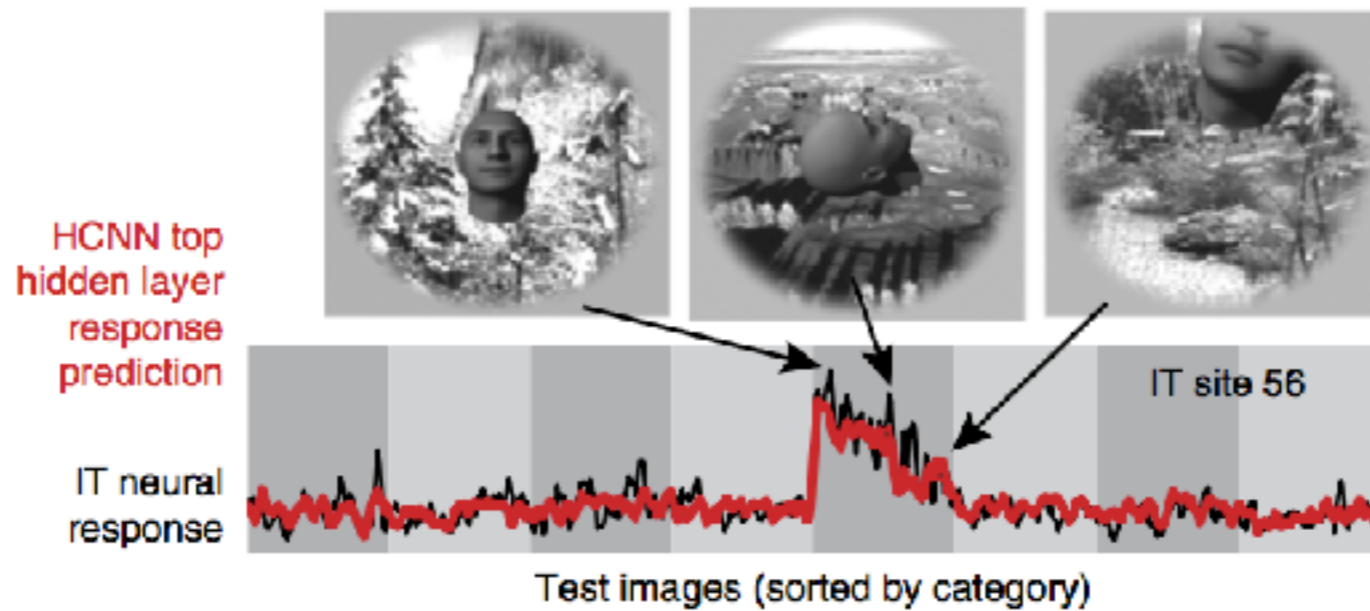
(Horikawa and Kamitani, 2015; *Nature Communications* 2017)

Critical features for neurons in each area

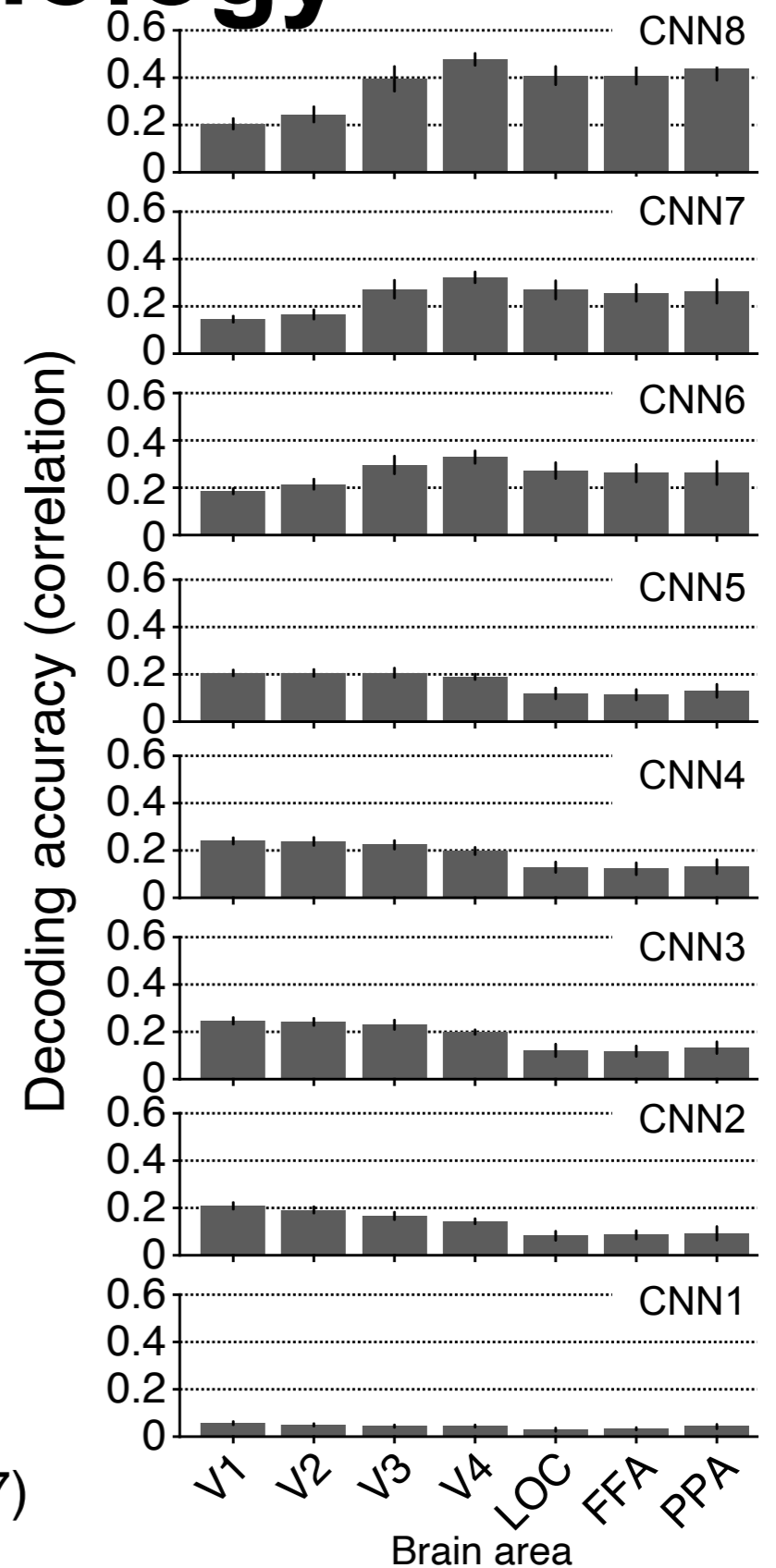
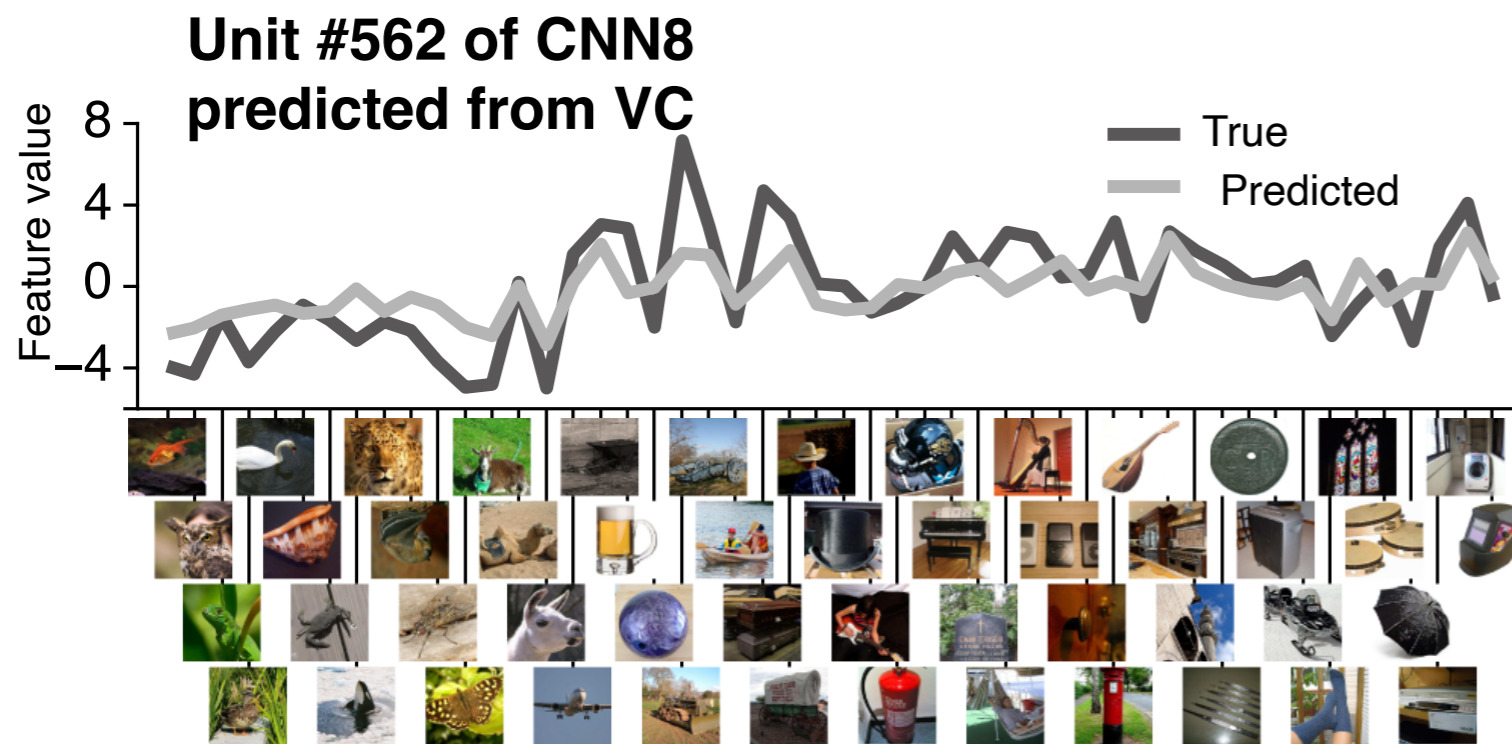
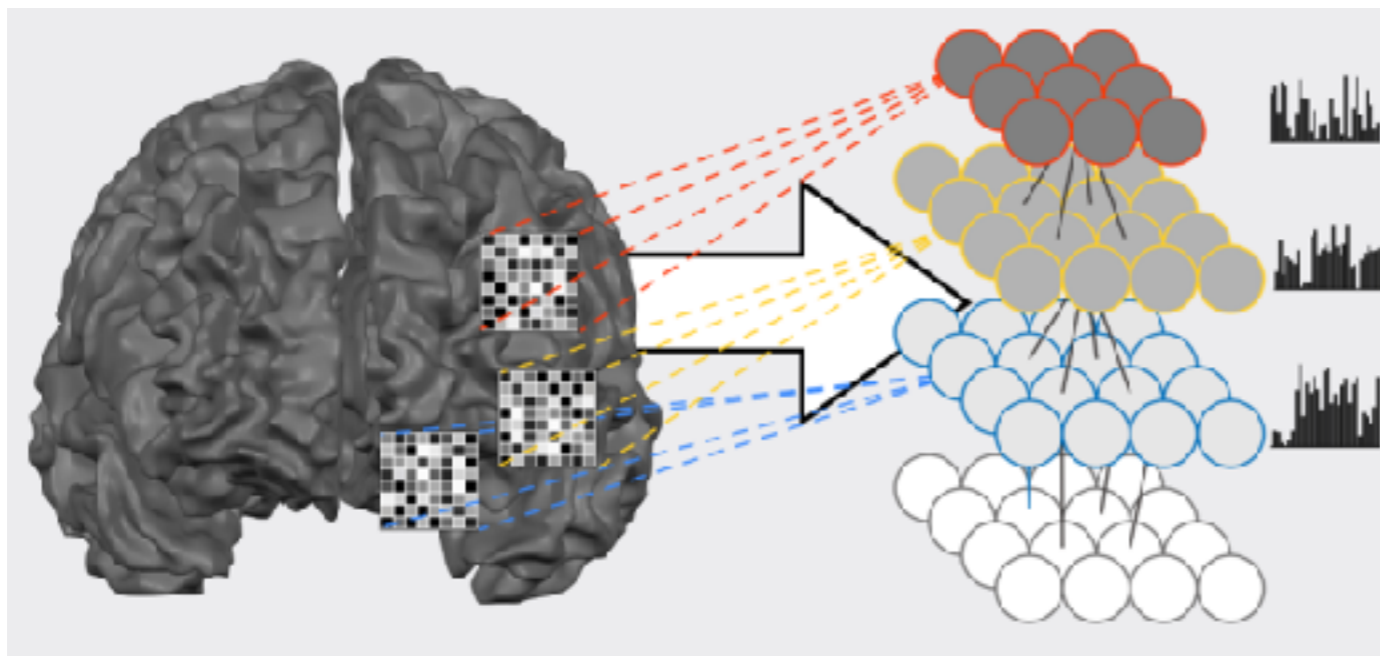
V2	V4	pIT	aIT
 	 	 	 
 	 	 	 
 	 	 	 
 	 	 	 



DNN-to-brain prediction

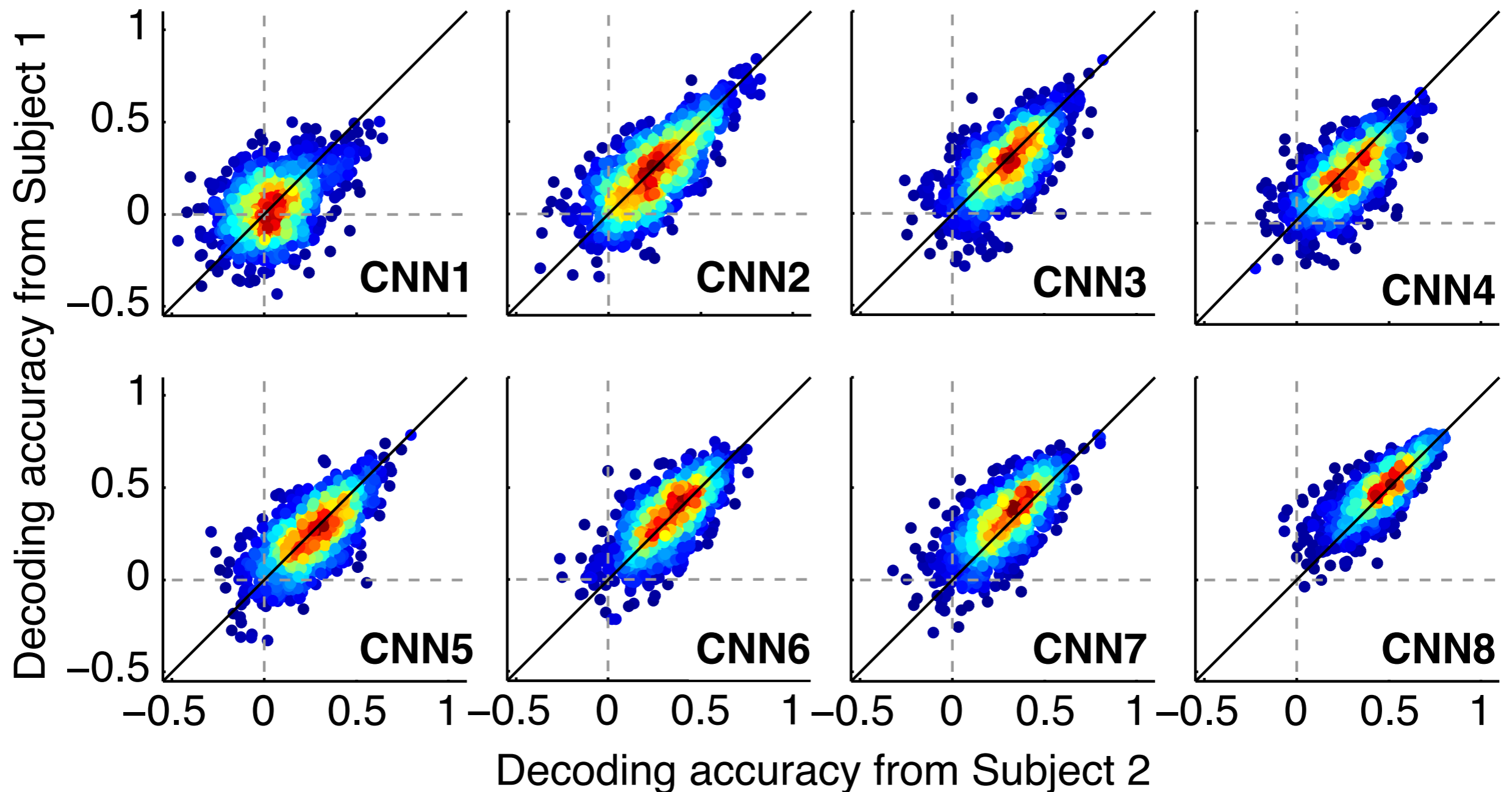


Brain-to-DNN decoding and hierarchical homology



(Horikawa and Kamitani, 2015; *Nature Communications* 2017)

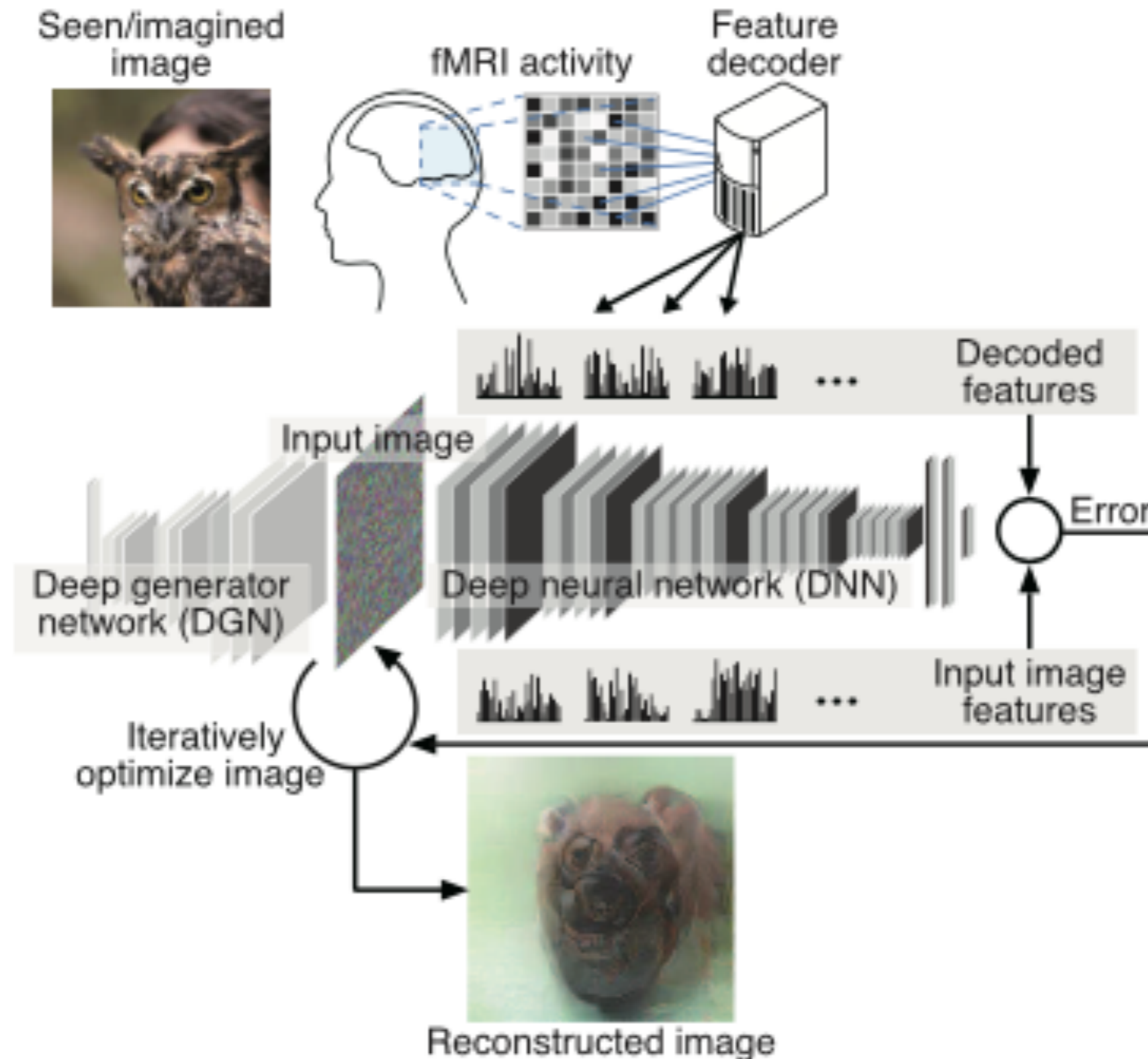
Decodable features are similar across subjects

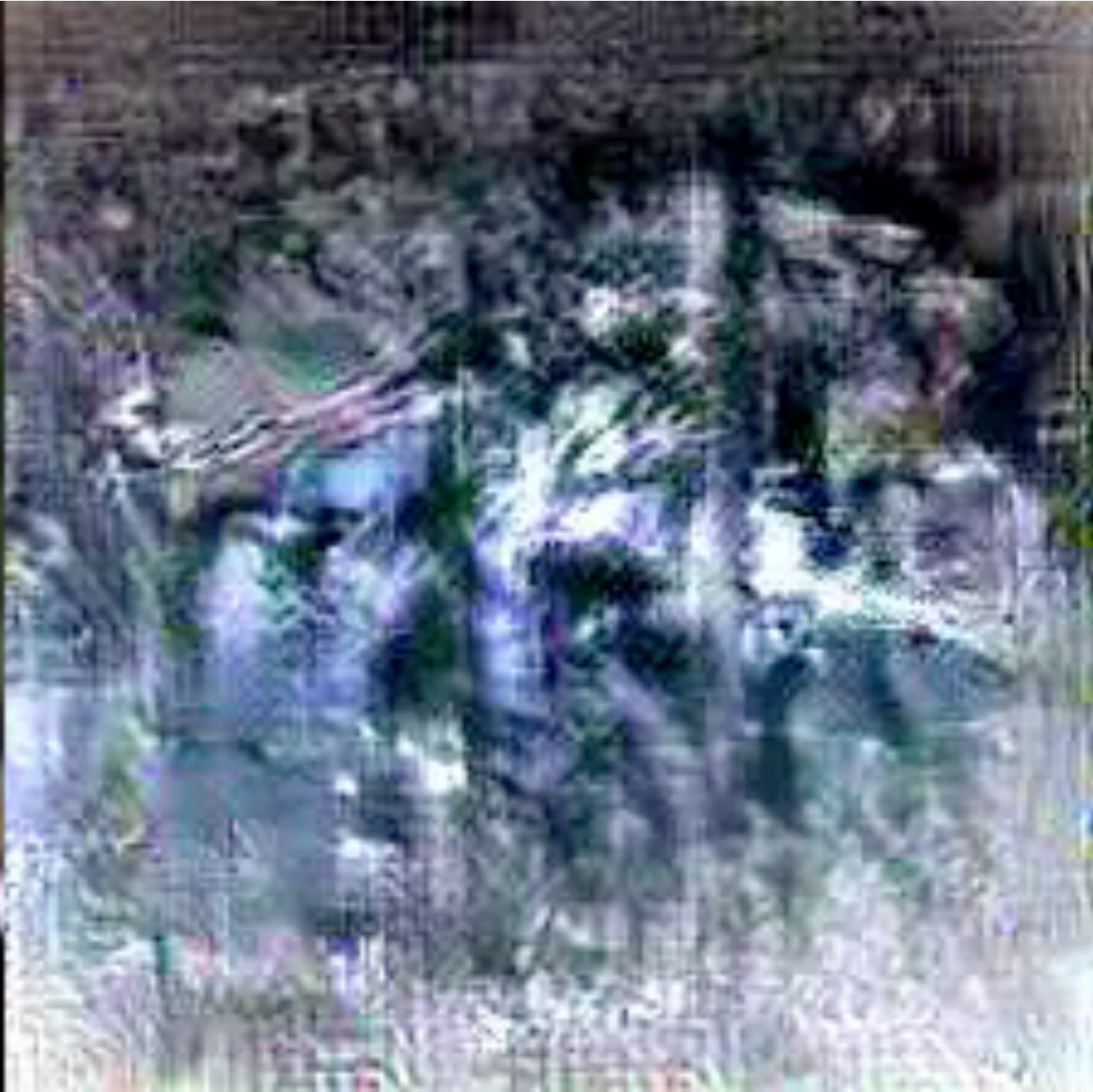


(Horikawa, Aoki, Tsukamoto, Kamitani, *Scientific Data* 2019)

Deep image reconstruction

(Shen, Horikawa, Majima, Kamitani, *bioRxiv* 2017; *Plos CB* 2019)







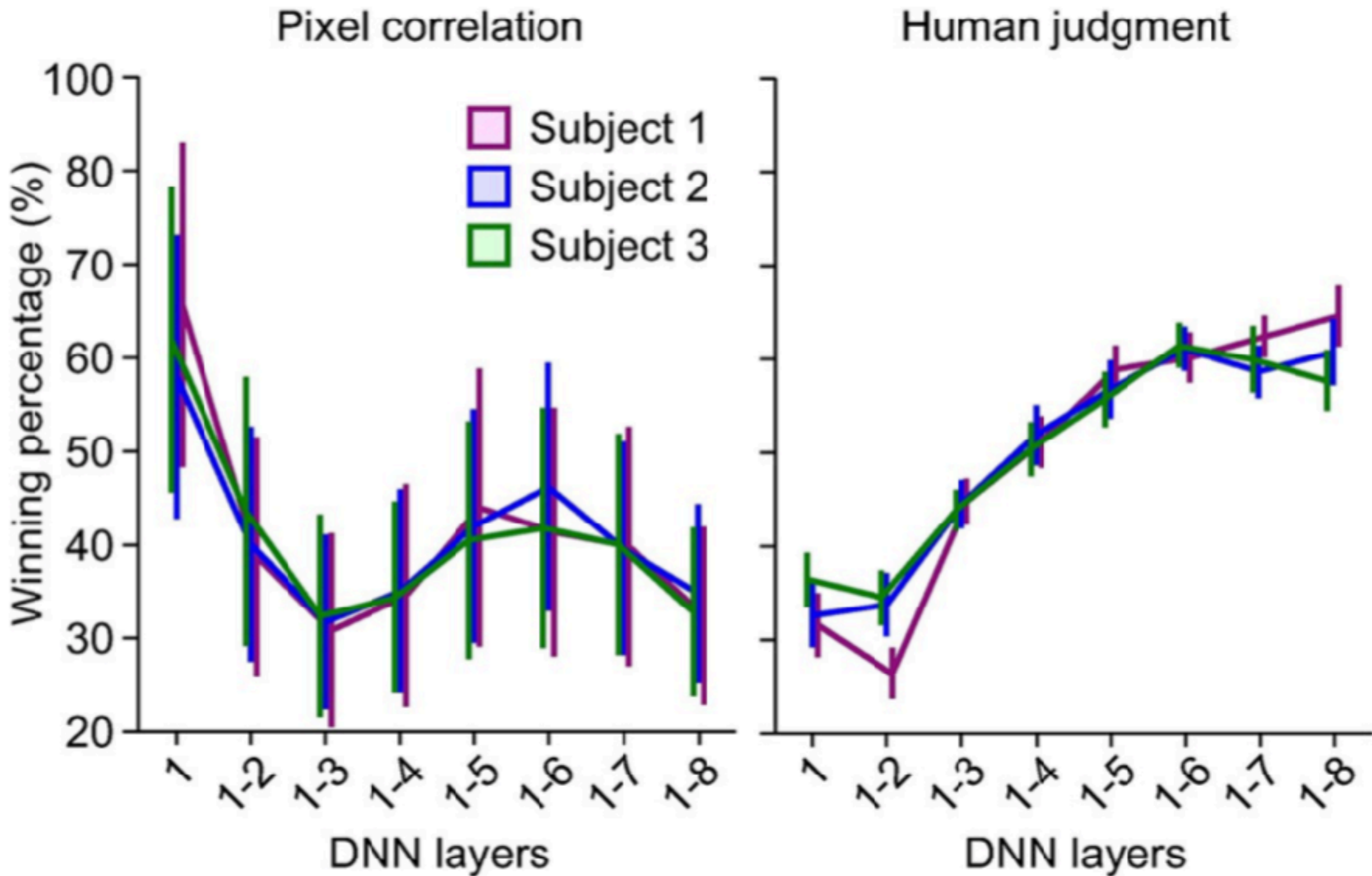












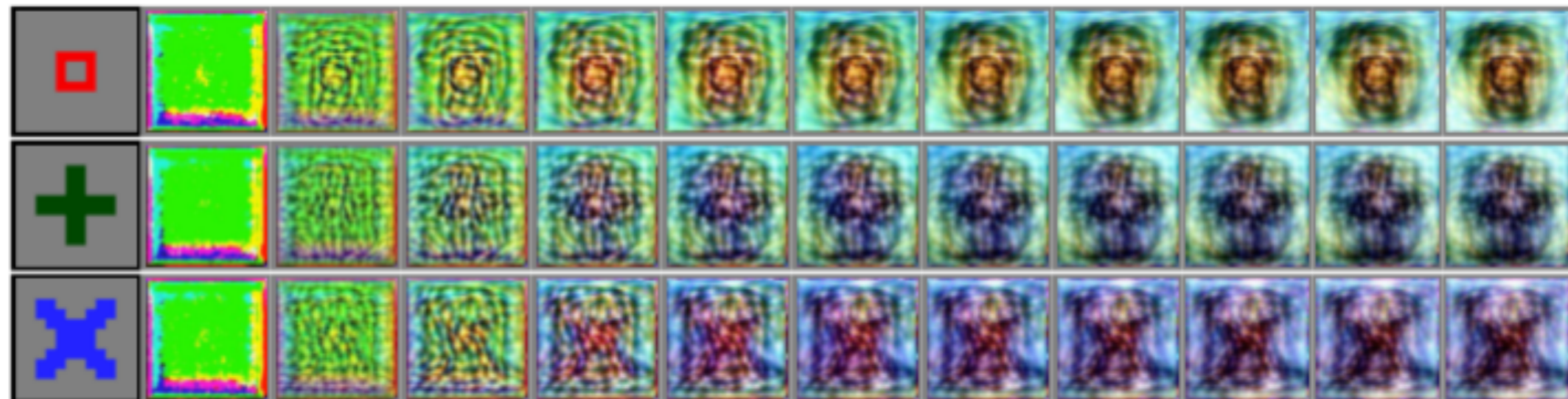
Use of multiple DNN layers improves perceptual quality of reconstruction.

(Shen, Horikawa, Majima, Kamitani, *Plos CB* 2019)

Imagery

Imagined

Reconstruction



(Shen, Horikawa, Majima, Kamitani, *bioRxiv* 2017; *Plos CB* 2019)

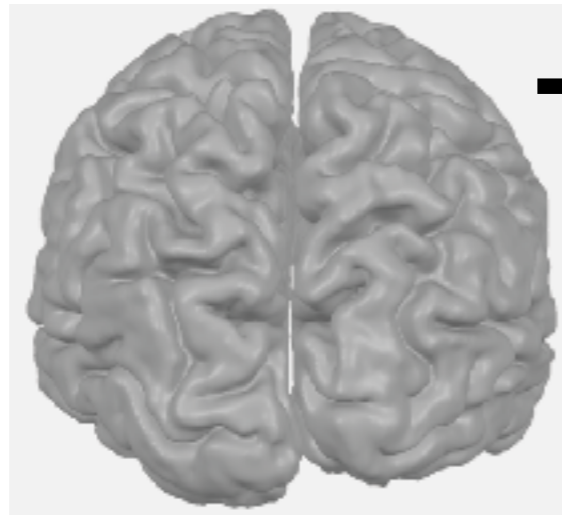
Attention



(Horikawa, Kamitani, *CCN* 2019; in preparation)

Summary

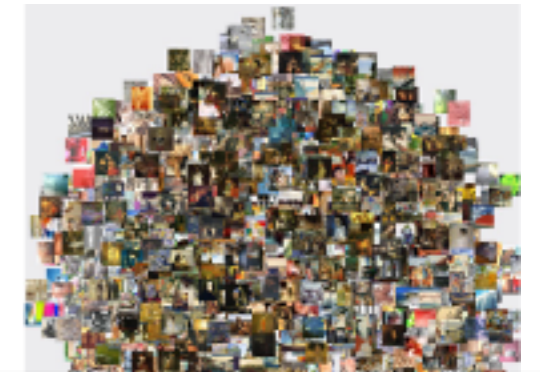
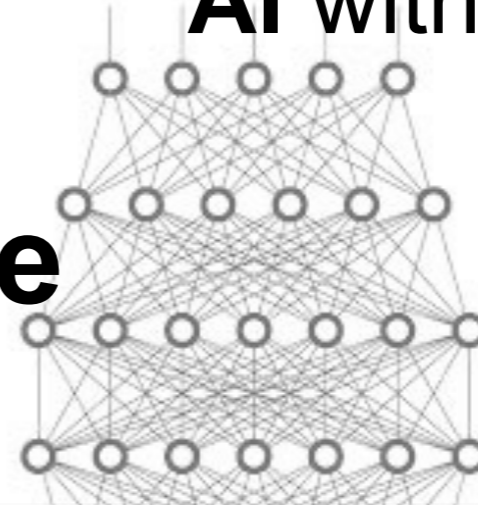
Brain in the world



Translate



AI with big data



AI as an interface between the brain and the mind

Decoding the mind



Brain-machine interface

Brain-based communication

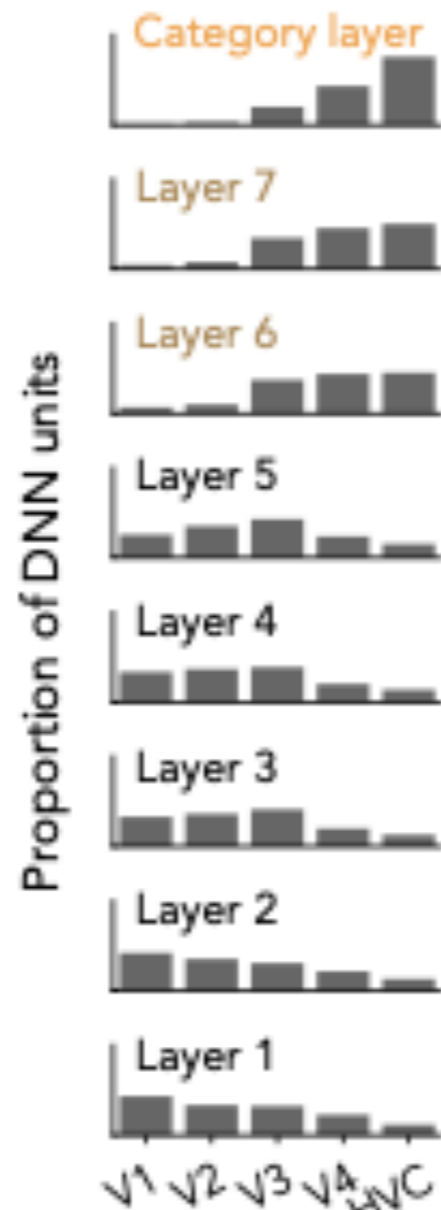
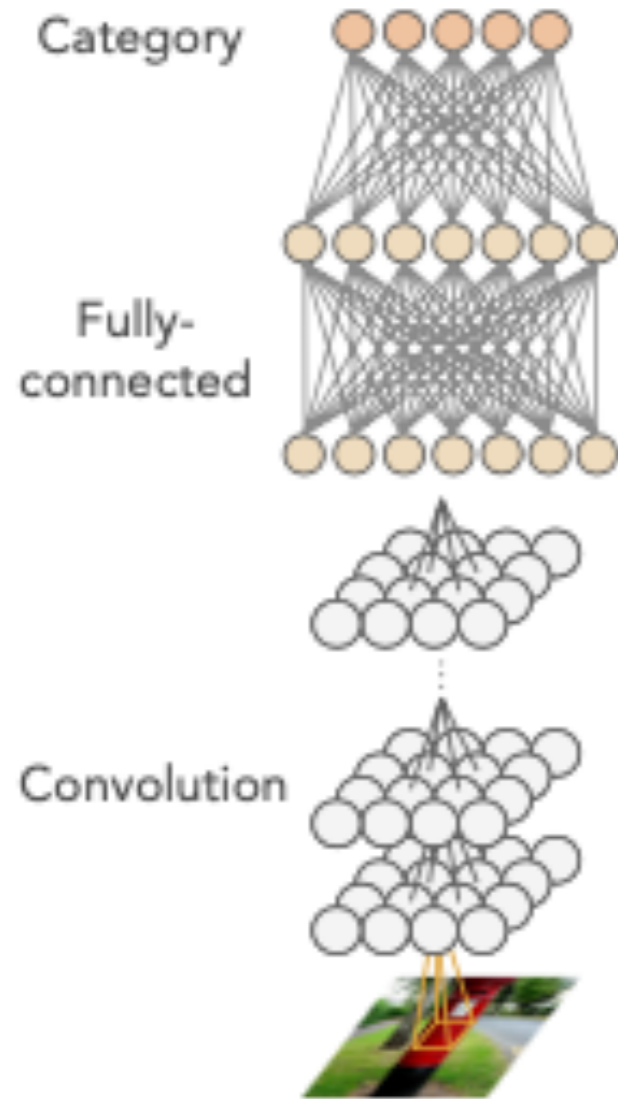
Diagnostics of mental disorders

Artistic expression

“Brain Hierarchy Score”

AlexNet:

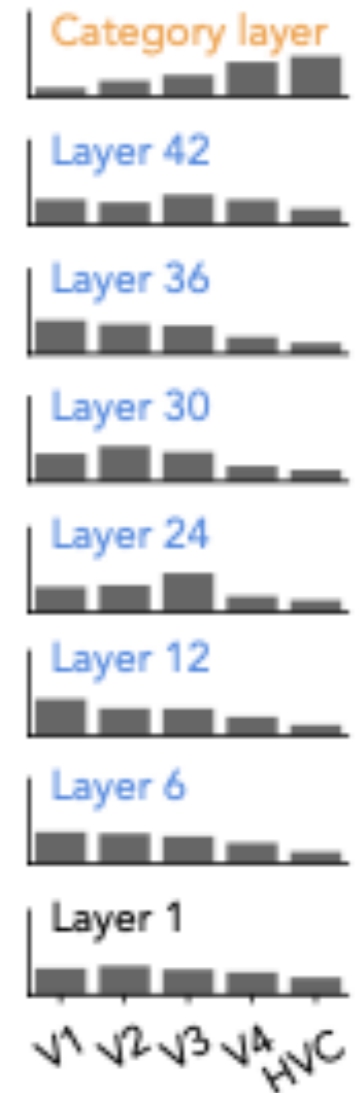
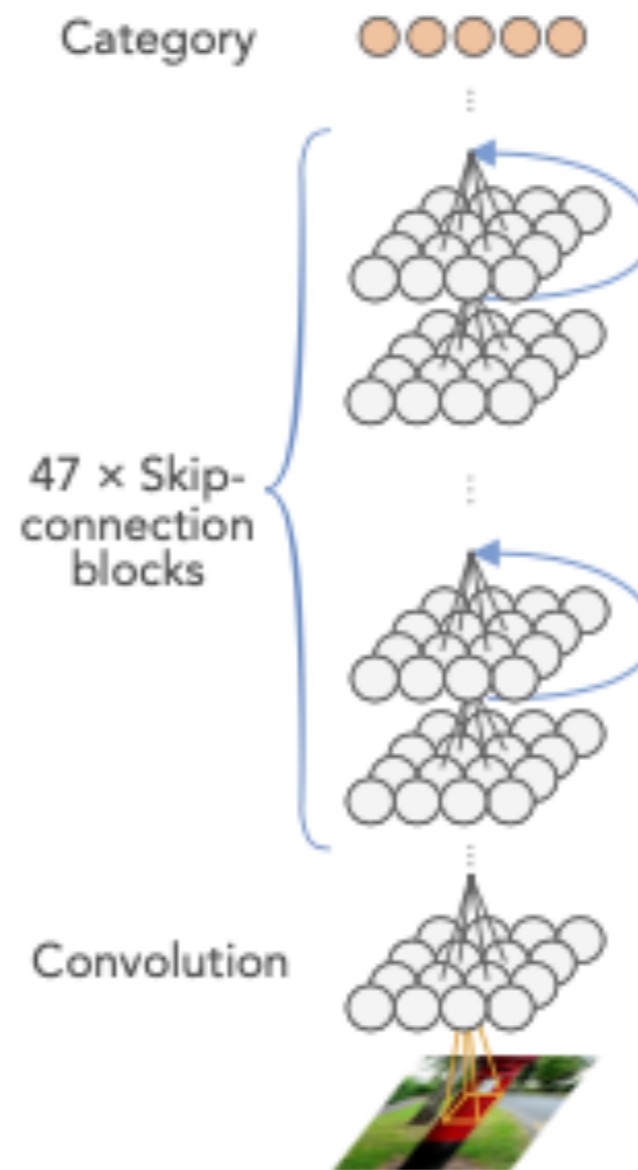
BH score = 0.50



Best predictive brain area

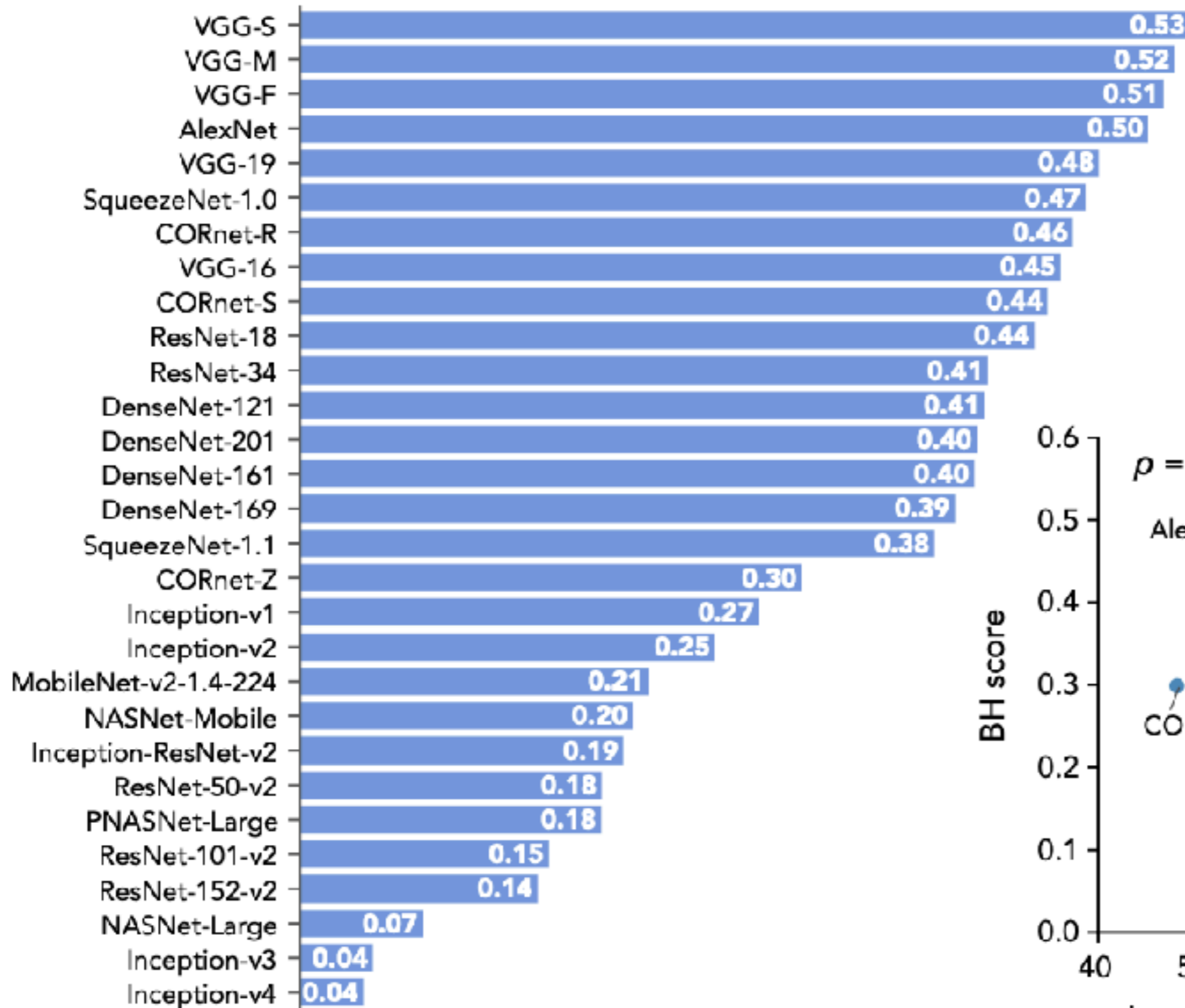
ResNet-152-v2:

BH score = 0.14

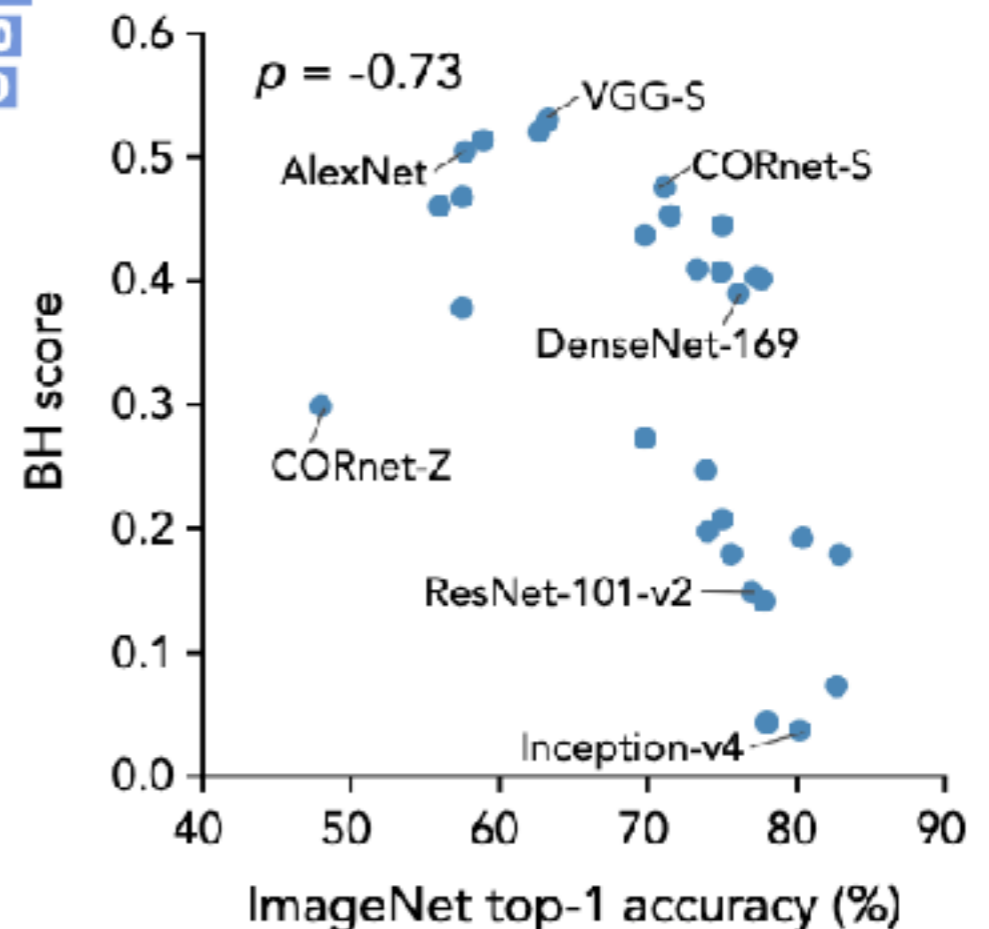


Best predictive brain area

BH score



Nonaka, Majima, Aoki,
Kamitani, bioRxiv 2020



High-performance DNNs are NOT hierarchically brain-like.

Vision AI is diverging from human vision?