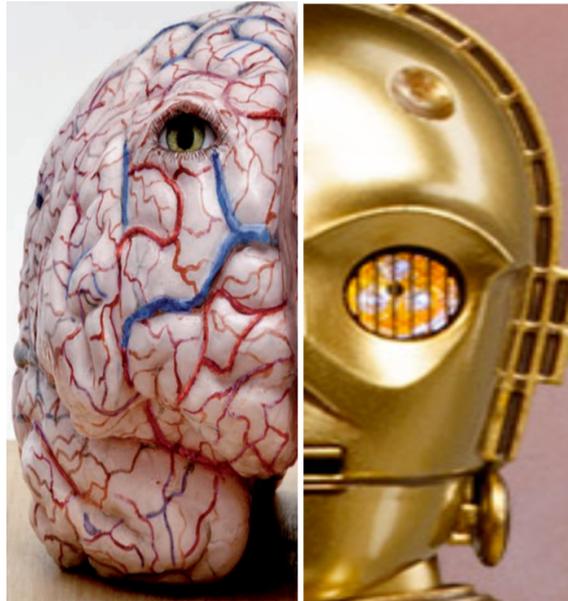


Is the study of Machine Learning distracting for Neurosciences?

Michel Dojat



Bio-inspired AI

Neural networks take over other machine-learning methods

Percentage of papers that mention each method

■ neural networks ■ bayesian networks ■ markov methods ■ evolutionary algorithms
■ support vector machines

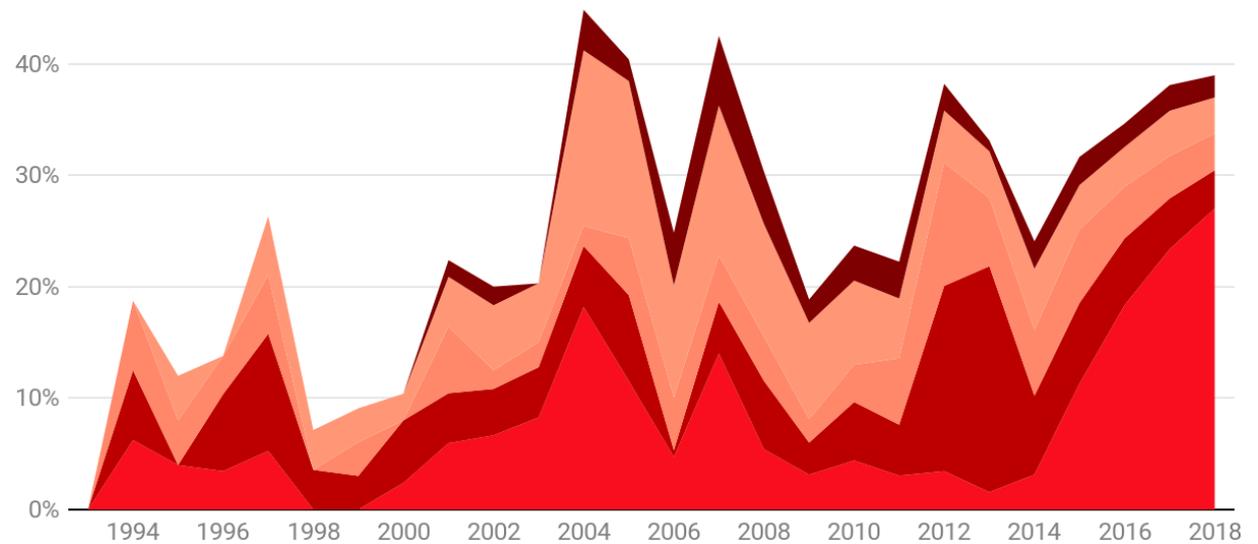


Chart: MIT Technology Review • Source: [arXiv.org](https://arxiv.org) • Created with Datawrapper

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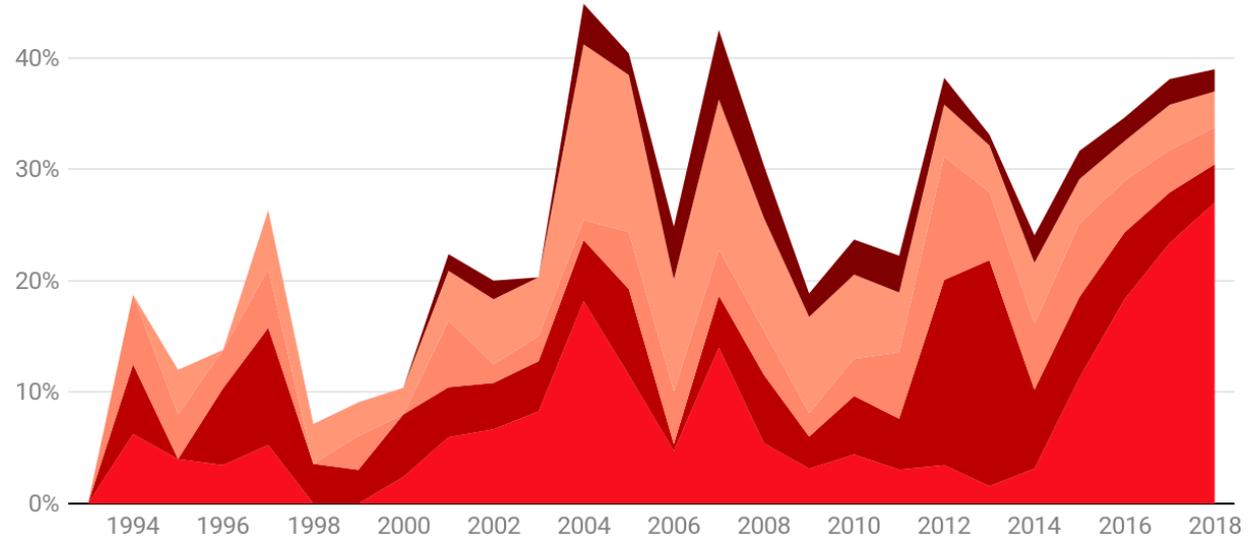
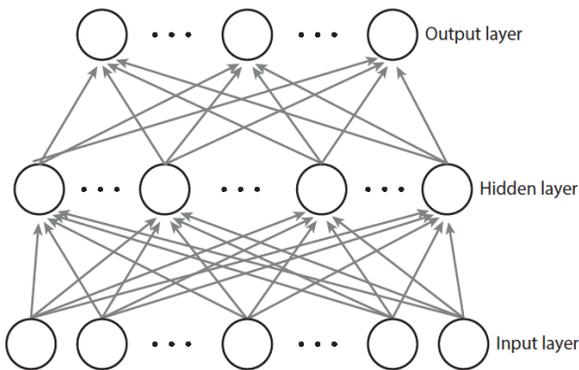
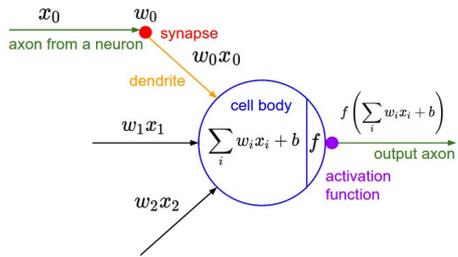
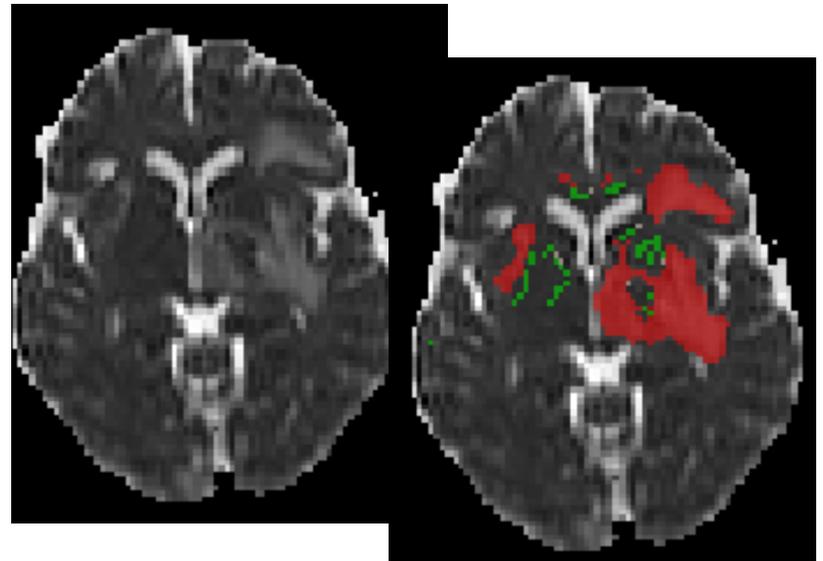
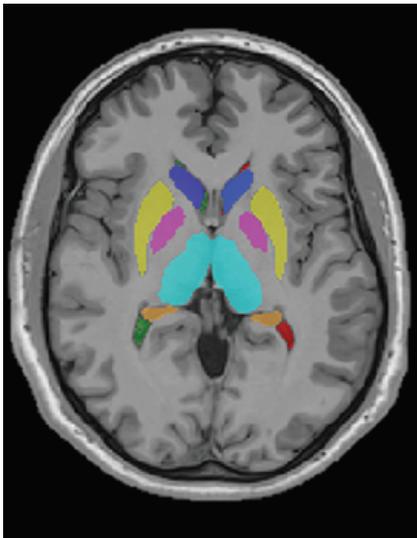


Chart: MIT Technology Review • Source: [arXiv.org](https://arxiv.org) • Created with Datawrapper



Computational Anatomy

- Quantification of brain structures
- Quantification of brain lesions
- Groups comparison



And the Winner is ...



Machine learning supervised approaches

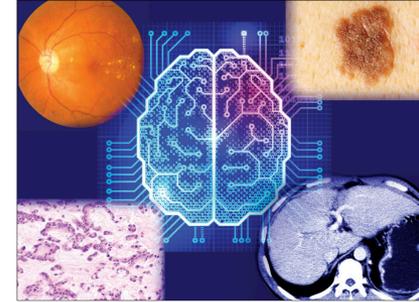
- ISLES 2017 challenge
 - Stroke : 14 participants, 14 NN
 - Trauma: 7 participants, 5 NN
 - Tumor: 22 participants, 19 NN, 1 SVM, 2 RF
- ISLES 2018
 - Stroke : 5 finalists NN
 - Tumor: Segmentation 3 finalists NN, Survival 3 finalists NN
 - ...



Life Science applications

- Classification / segmentation / detection

Moeskops et al TMI 2016; Rajchl et al MIDL 2018 (*brain tissue*);
Dolz et al. Neuroimage 2018 (*brain structures*); Kamnitsas et al MediA 2016 (*brain lesions*)
Kleesiek et al Neuroimage 2016 (*brain extraction*); Havaei et al MediA 2016 (*brain tumors*)
Suk et al NeuroImage 2014 (*AD/MCI*)
Zhao et al MediA 2017; Suk et al NeuroImage 2016;
Kin et al Neuroimage 2016 (*functional brain networks*)
Ciampi et al Scient Rep 2017 (*lung nodules*); Esteva et al Nature 2017 (*skin cancer*)



[Quer et al 2017 Lancet]

- Synthetic image generation

Nie et al Miccai 2017 (*MR-CT*); Liu et al Radiology 2017 (*MR-CT*); Zhao et al Media 2018 (*retinal images*)

- Predictive models

Polpin et al Nat Bio Eng 2018 (*cardiovascular risk*); Miotto et al. Scient Rep 2016 (*deepPatient*)

- Processing

Rajchl et al MIDL 2018 (*automatic process for segmentation*), reconstruction, denoising, registration (see Litjens Media 2017)

- Retrieval

Anavi et al Spie 2016

Open methodological questions

- Influence of data processing
- Data from different centres
- Images augmentation
- Strategy for selection of the best architectures for a given domain application
- Use in clinical routine

International Conference on
Medical Imaging with Deep Learning

London, 8 - 10 July 2019

info@mid.io | [@midl_conference](https://twitter.com/midl_conference)



Open methodological questions

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Finger printing
Radiomics

FLI-IAM web portal

Shanoir
Shanoir-SA

Populse
MP3
Predimed

**HEALTH
DATA
HUB**

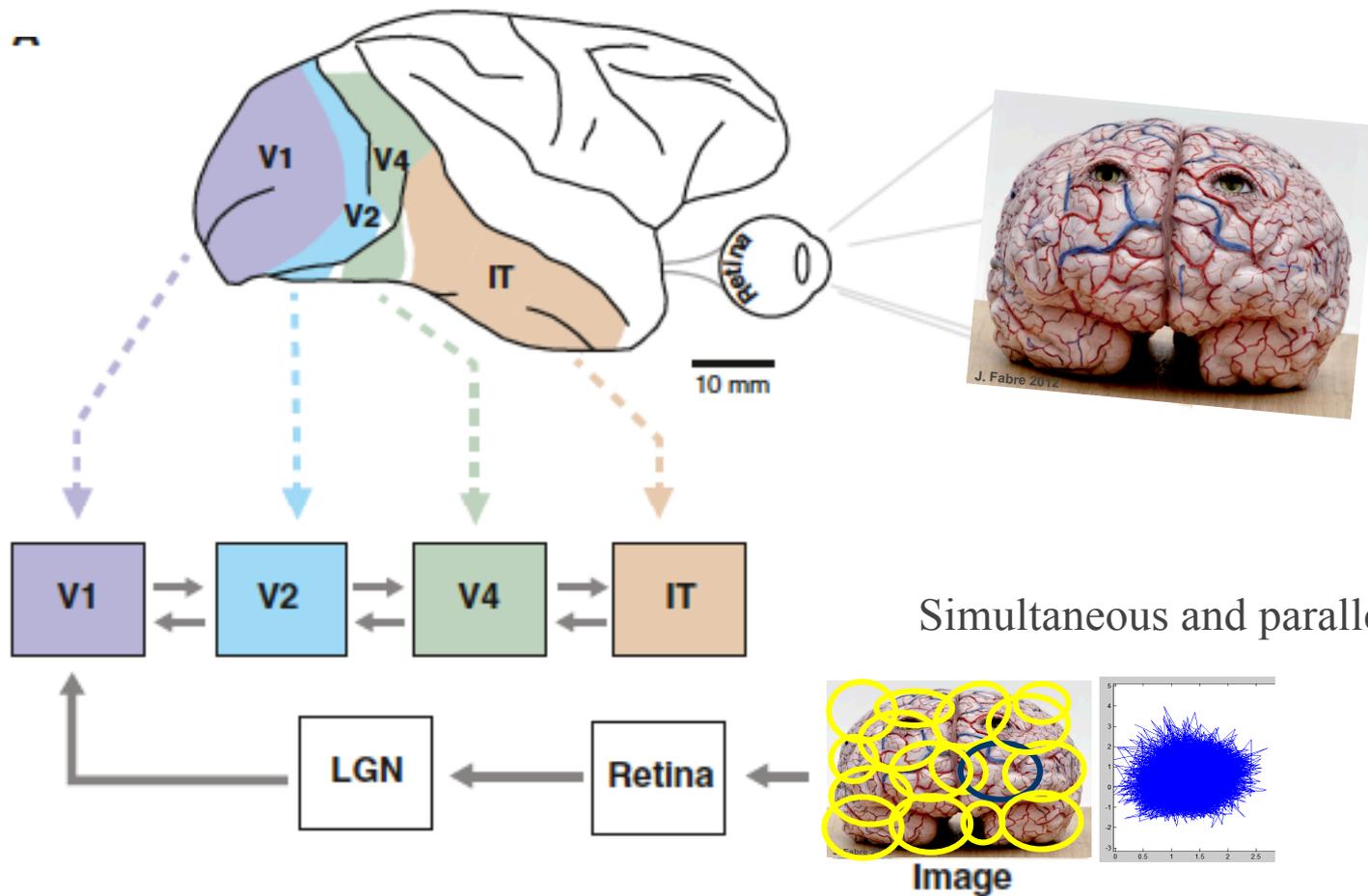
Development of large databases

ANN & Neurosciences – Cross fertilization



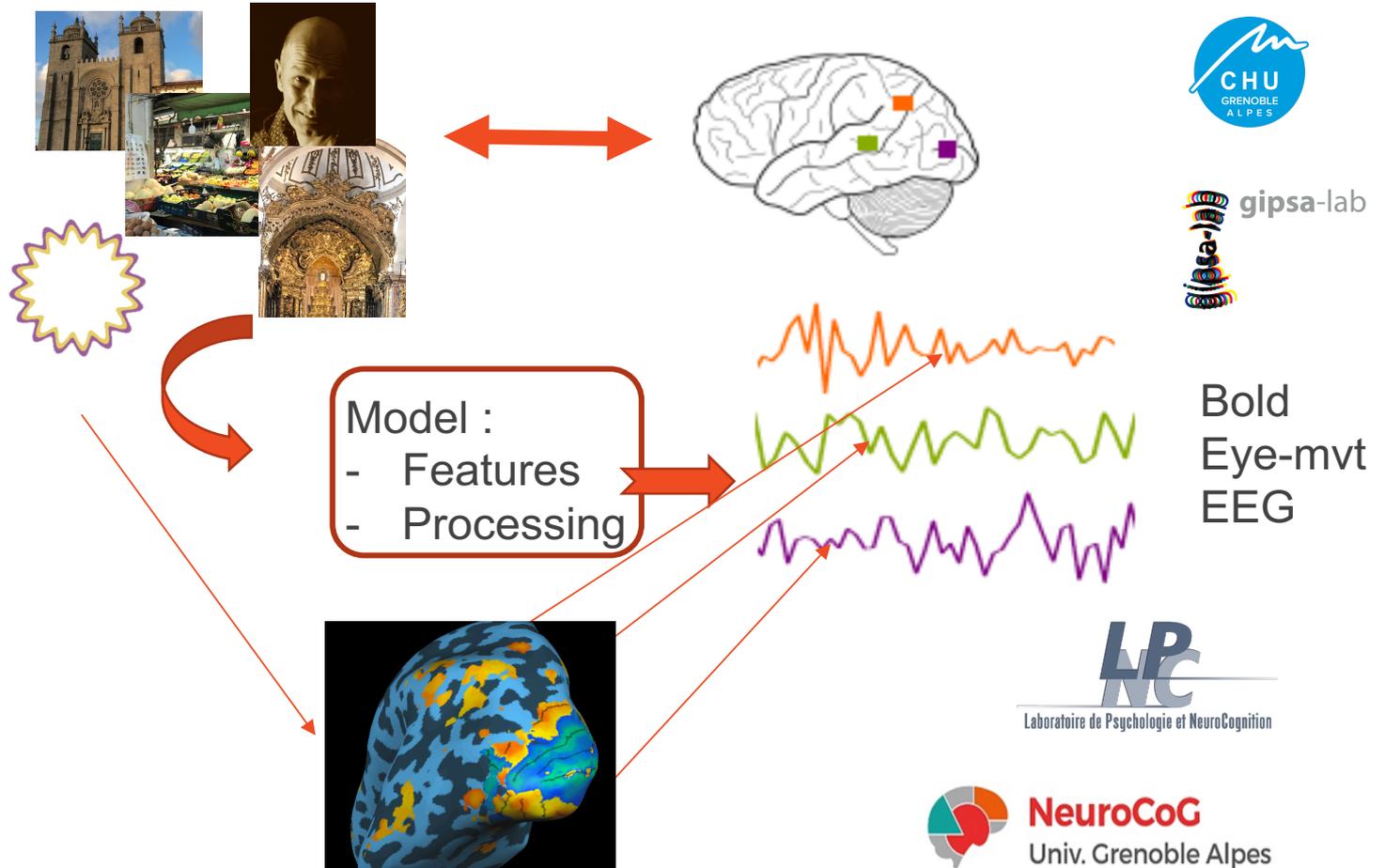
- A case-study: The Human Visual System

Mammalian visual system

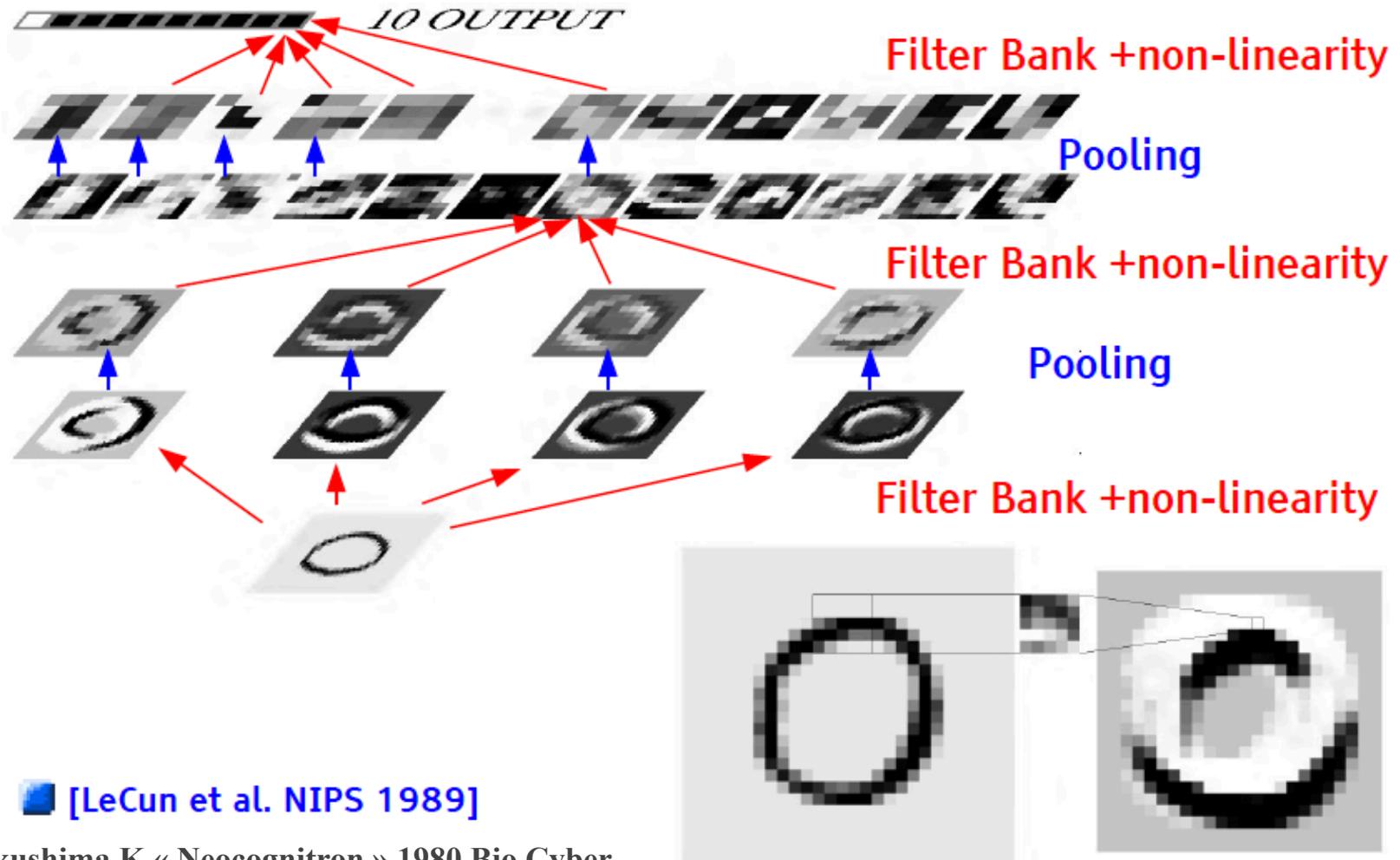


[adapted from Cox & Dean curr bio 2014]

Visual representation in the Human Brain



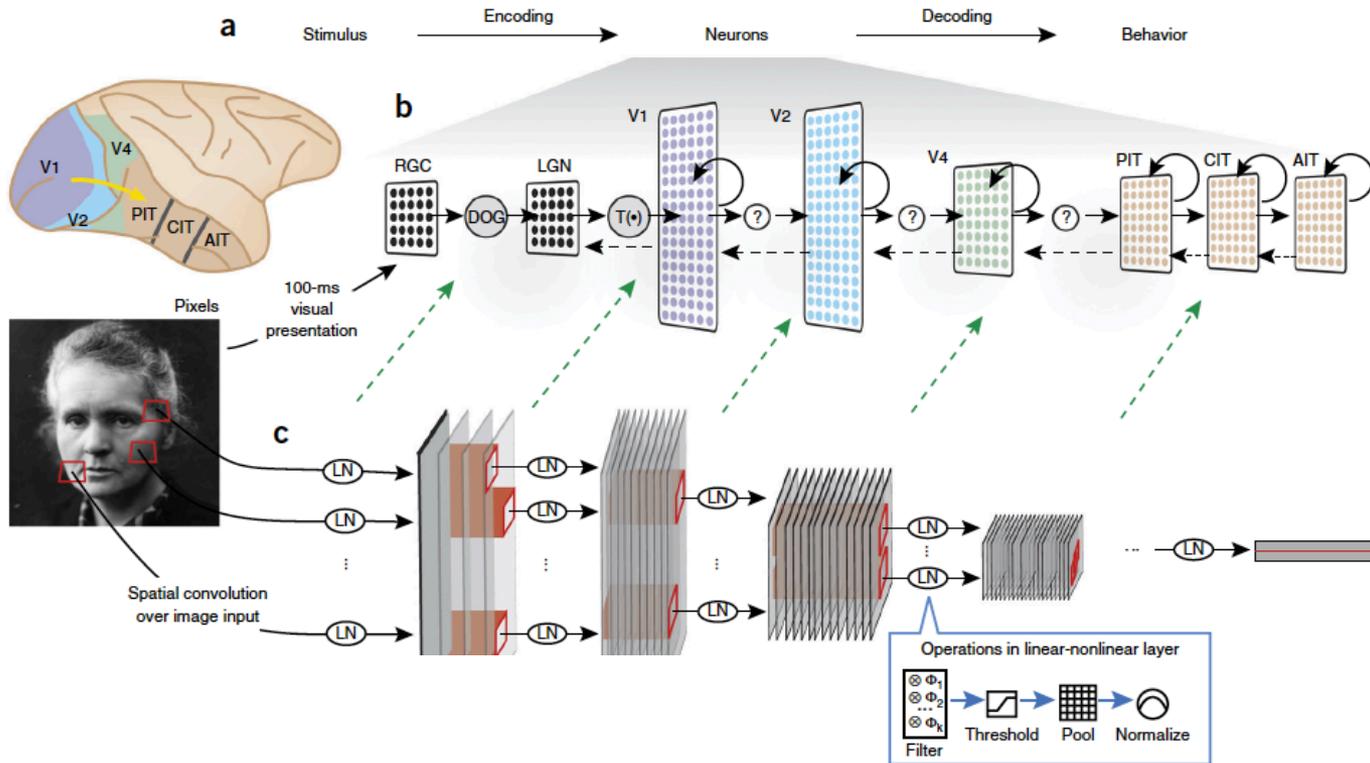
Convolutional NN



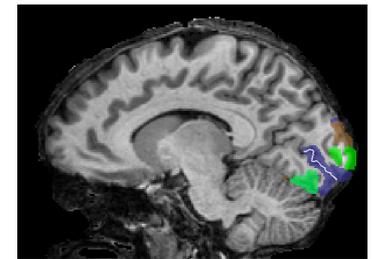
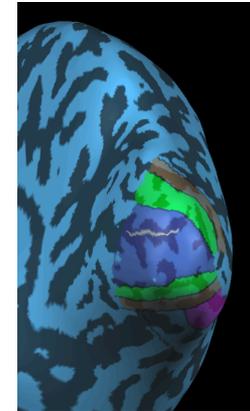
■ [LeCun et al. NIPS 1989]

Fukushima K « Neocognitron » 1980 Bio Cyber

CNN as a model of the visual system ...



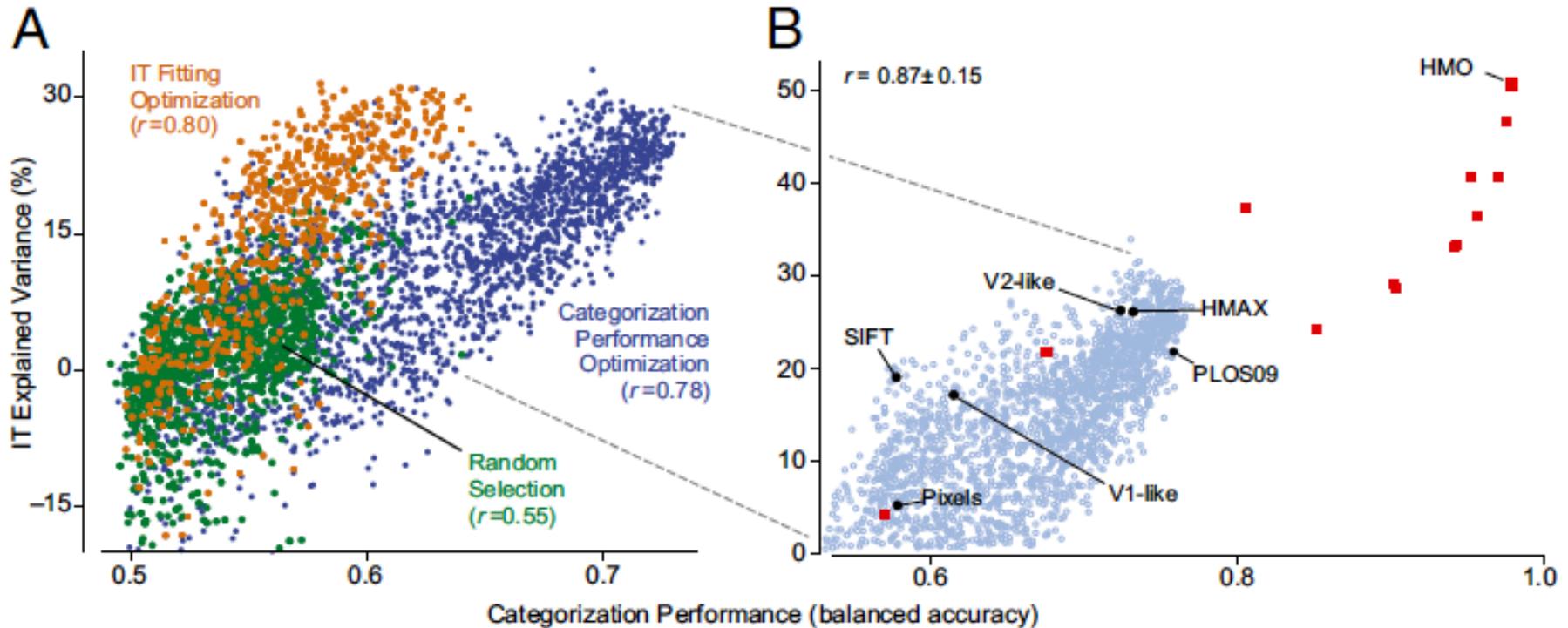
- ✓ Receptive field
- ✓ Hierarchical model
- ✓ Max pooling
- ✓ Normalisation



[Yamins and Dicarlo Nat Neuro 2016]

[Dojat 2017]

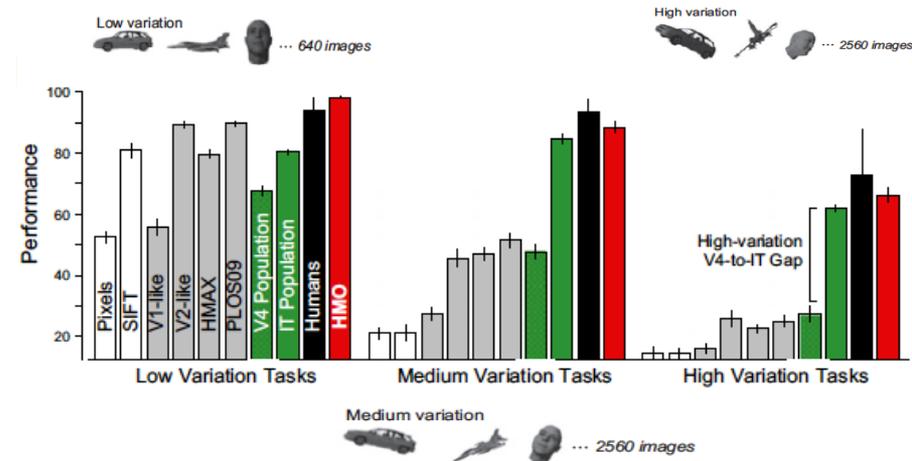
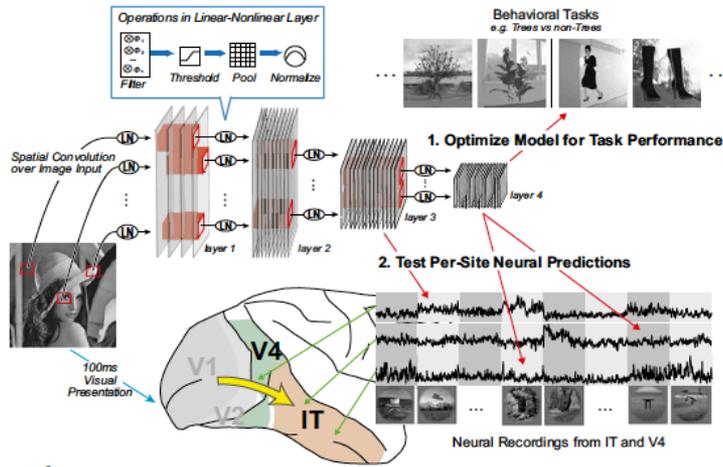
Hierarchical models for neural responses prediction



[Yamins et al 2014 PNAS]

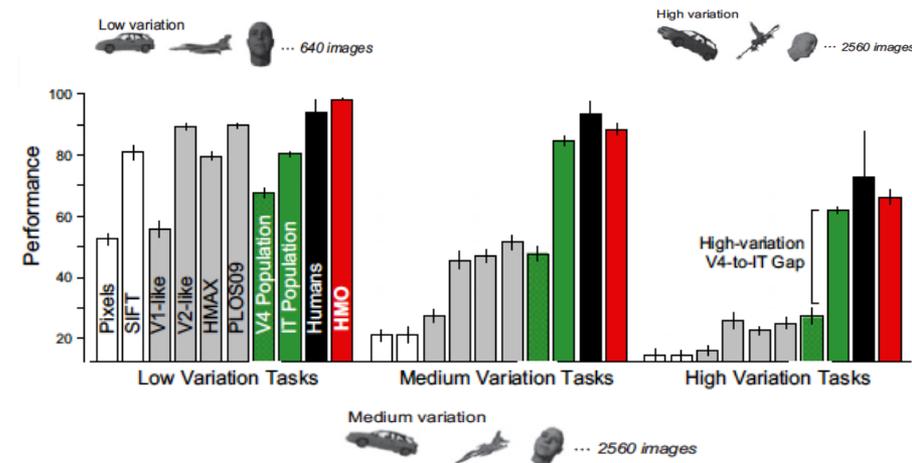
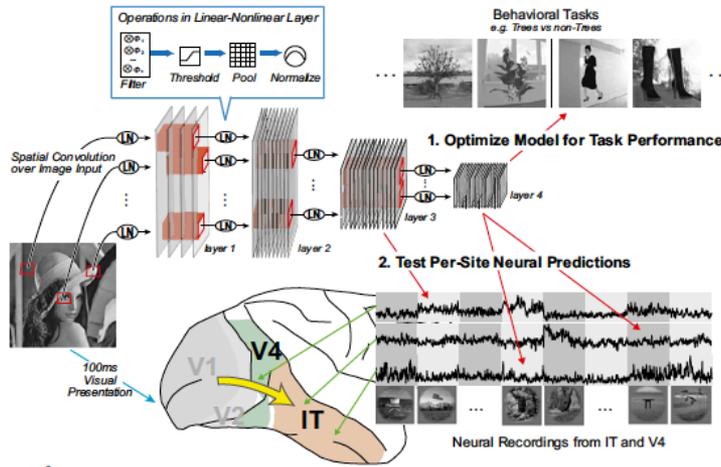
Hierarchical models for neural responses prediction

[Yamins et al 2014 PNAS]

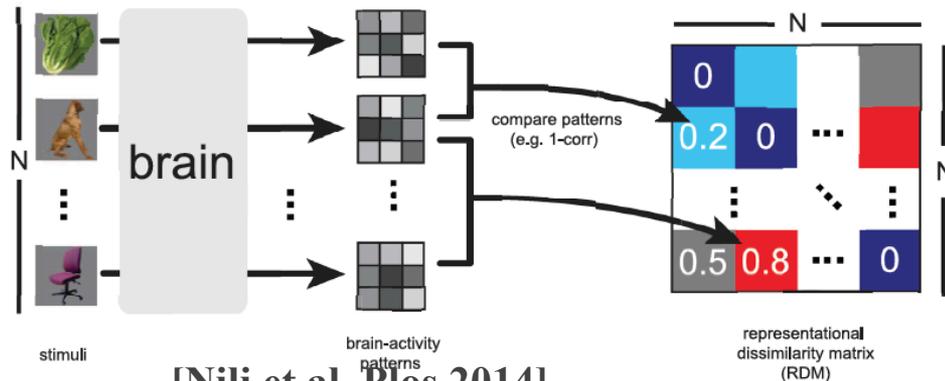


Hierarchical models for neural responses prediction

[Yamins et al 2014 PNAS]

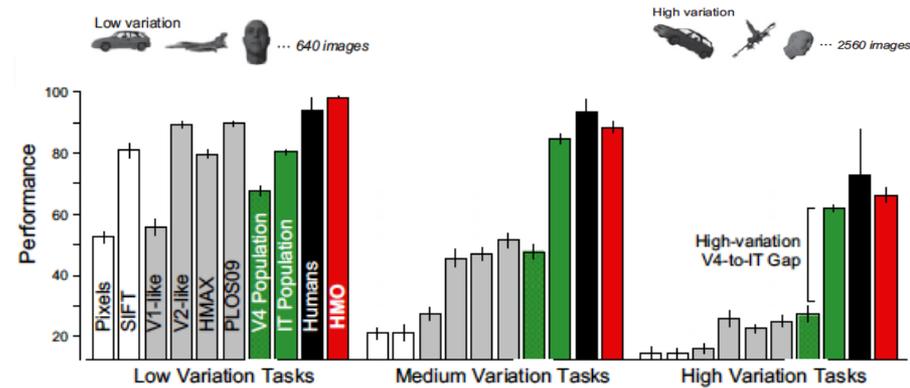
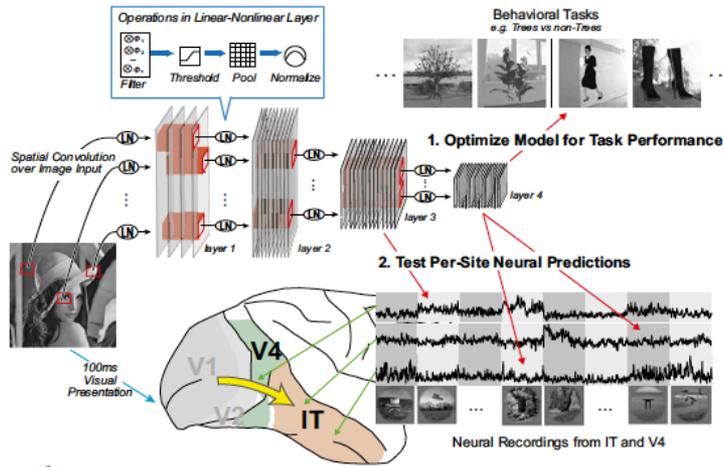


Representation dissimilarity matrices

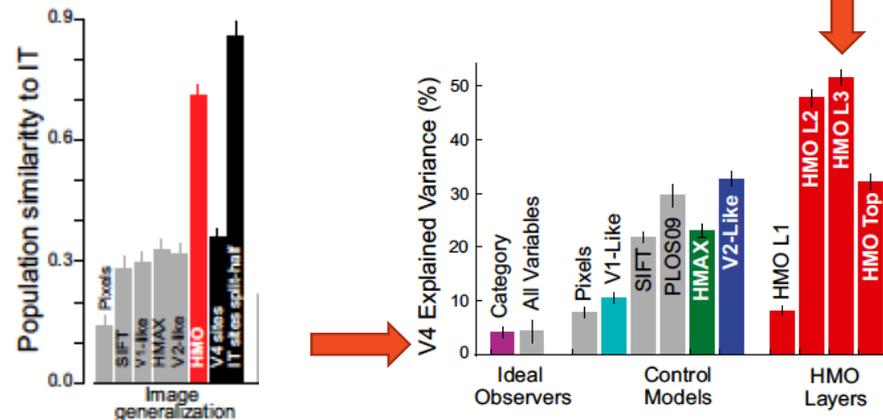


Hierarchical models for neural responses prediction

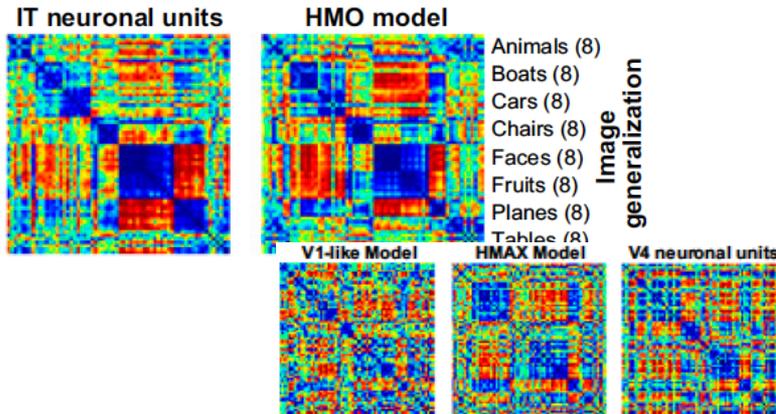
[Yamins et al 2014 PNAS]



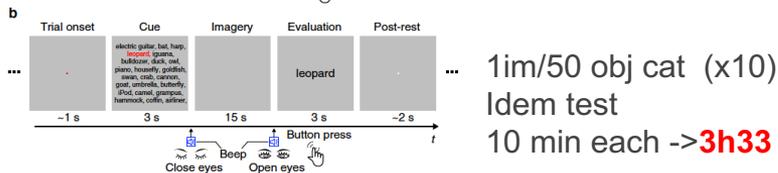
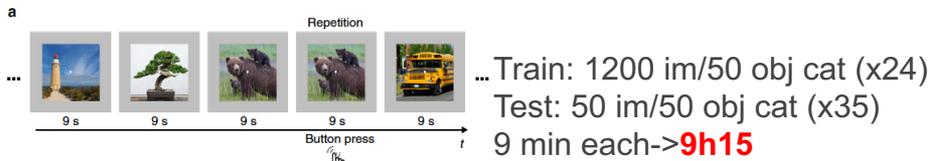
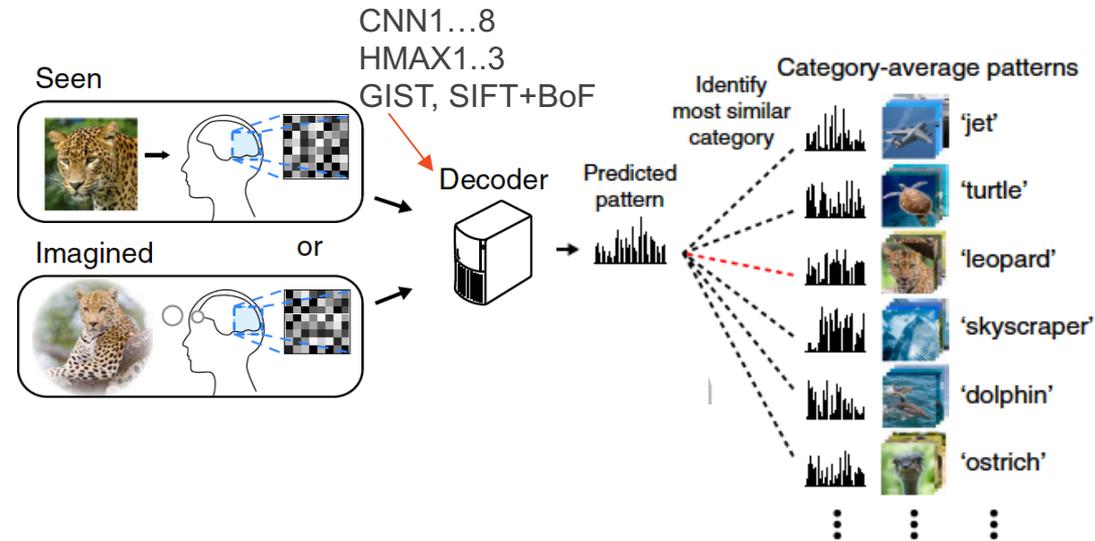
Medium variation
... 2560 images



Representation dissimilarity matrices

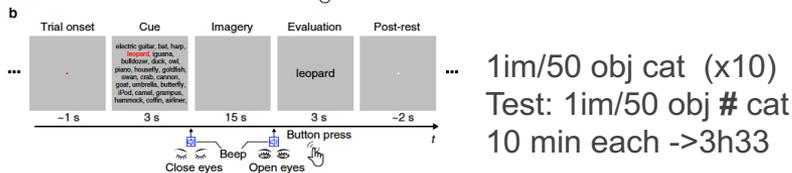
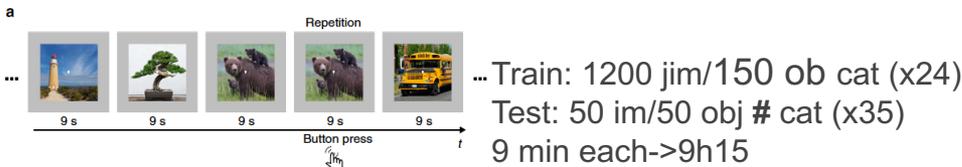
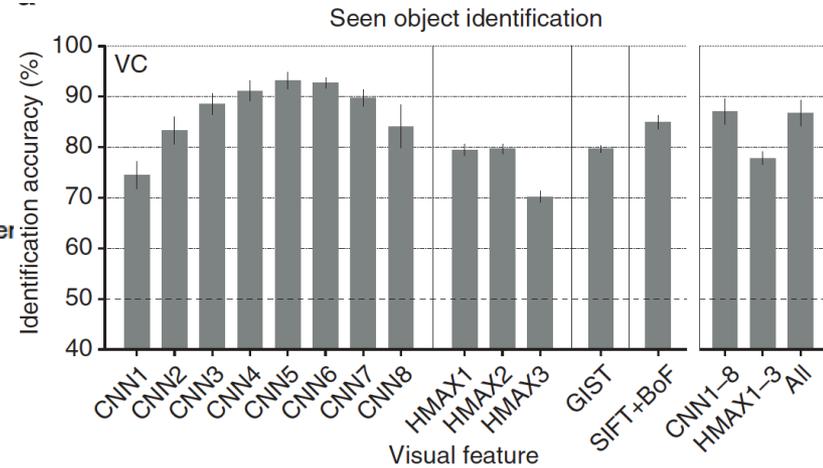
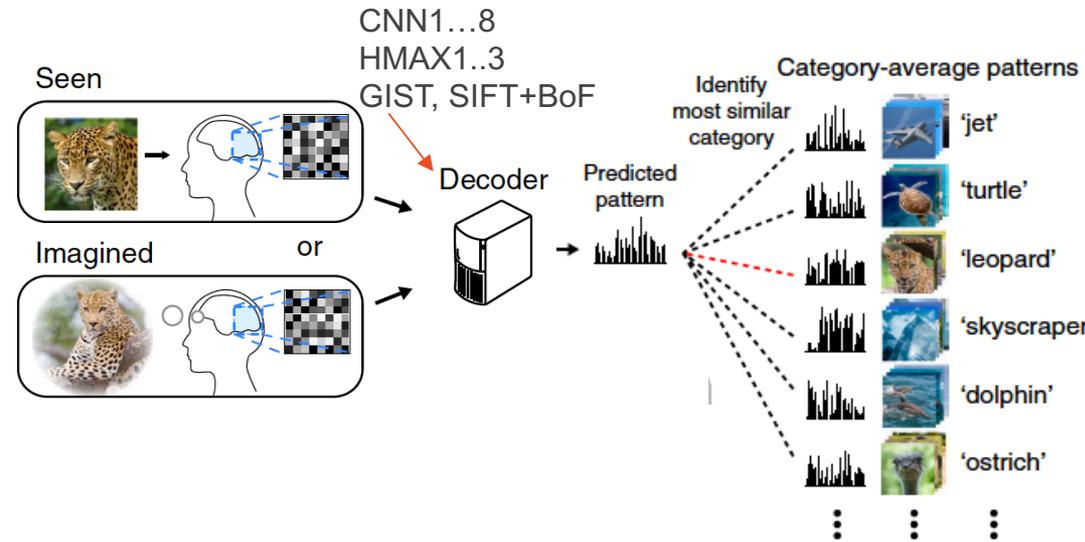


Seen/imagined object arbitrary categories



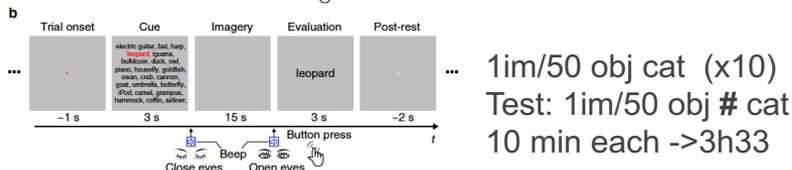
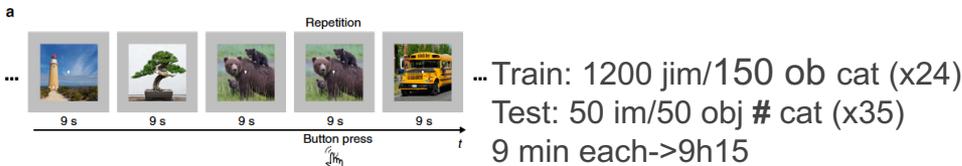
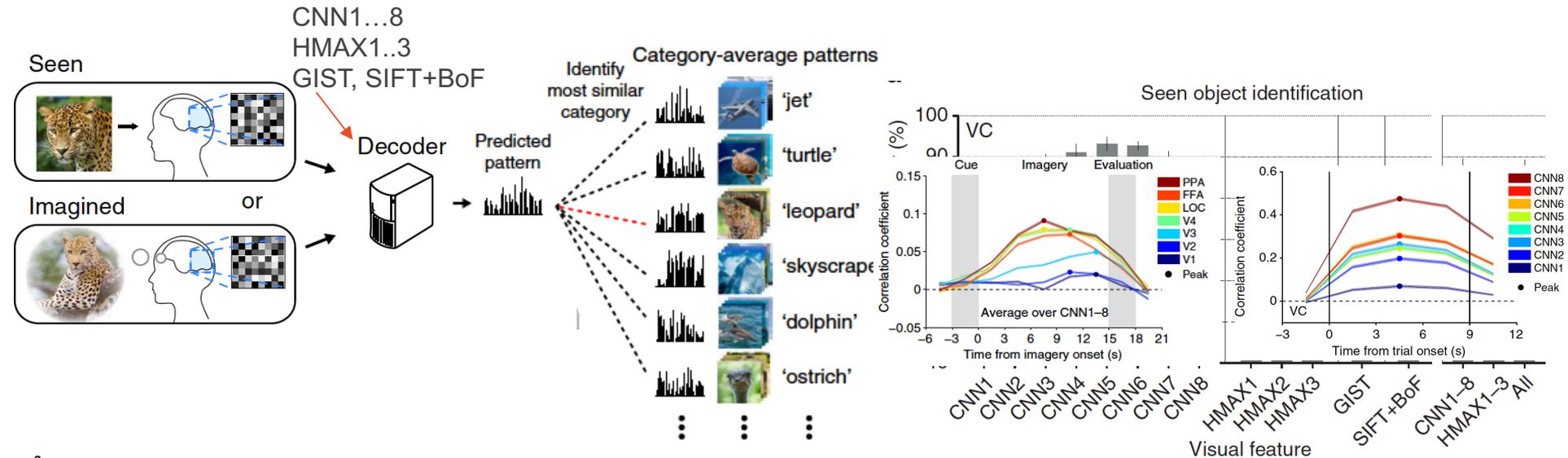
[Horikawa and Kamitani Nat Comm 2018]

Decoding object arbitrary categories



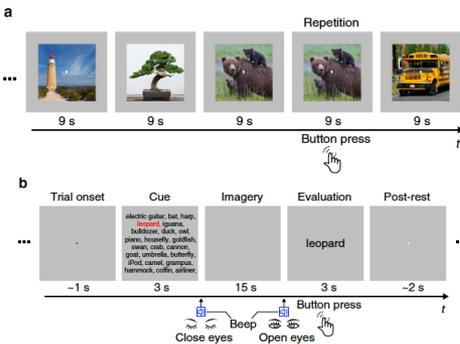
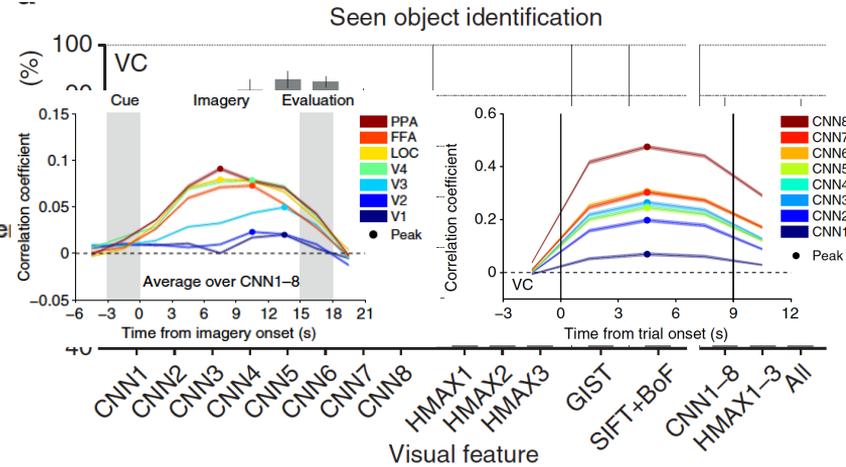
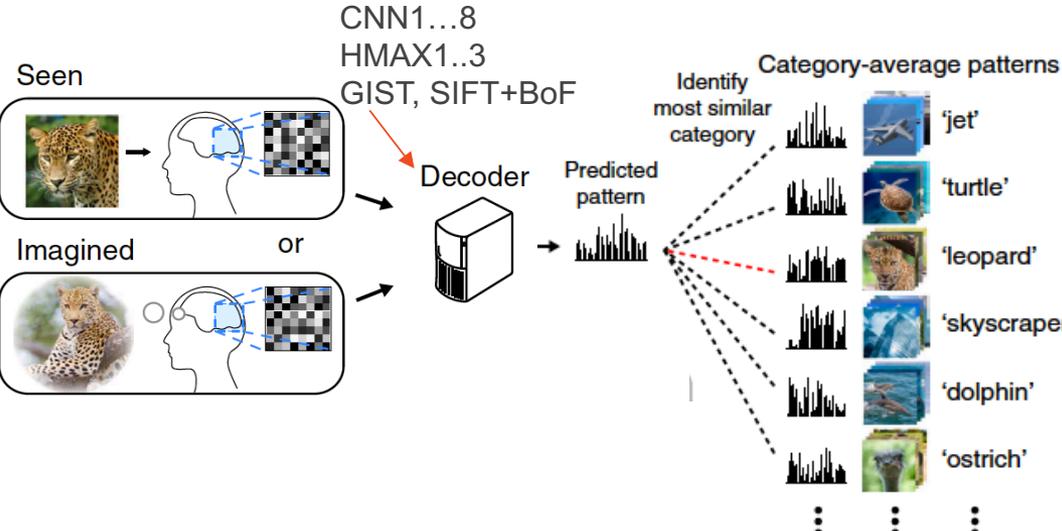
[Horikawa and Kamitani Nat Comm 2018]

Decoding object arbitrary categories



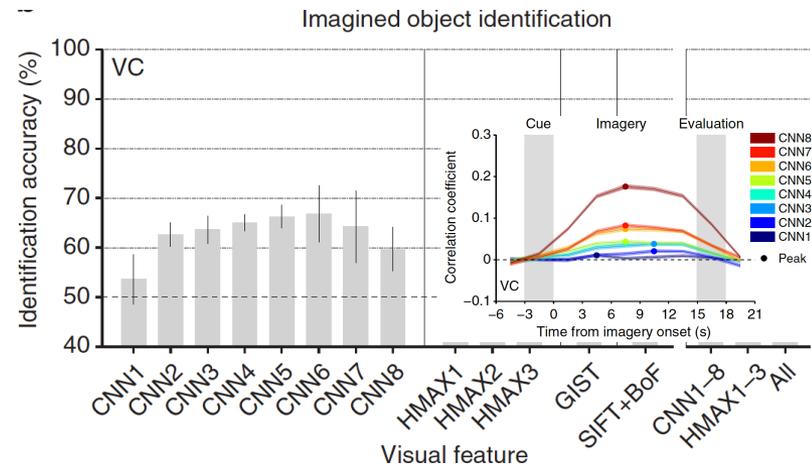
[Horikawa and Kamitani Nat Comm 2018]

Decoding object arbitrary categories



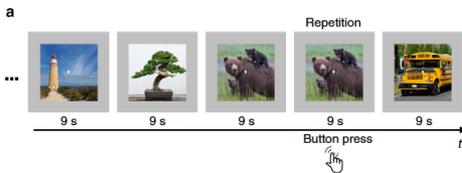
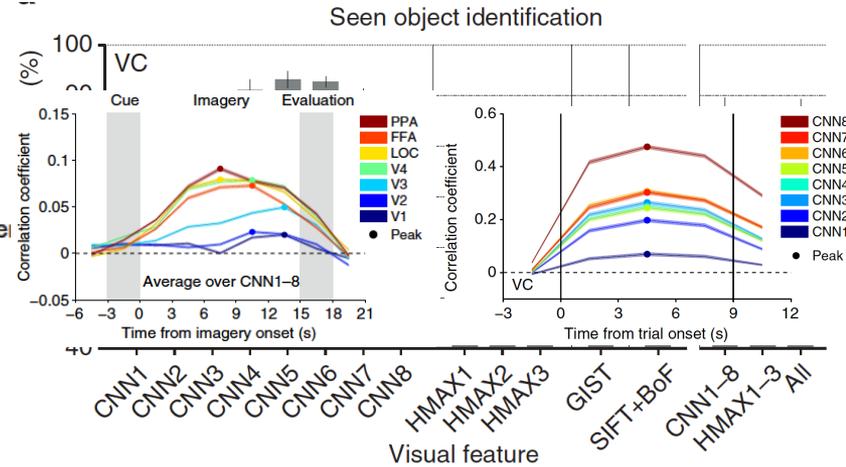
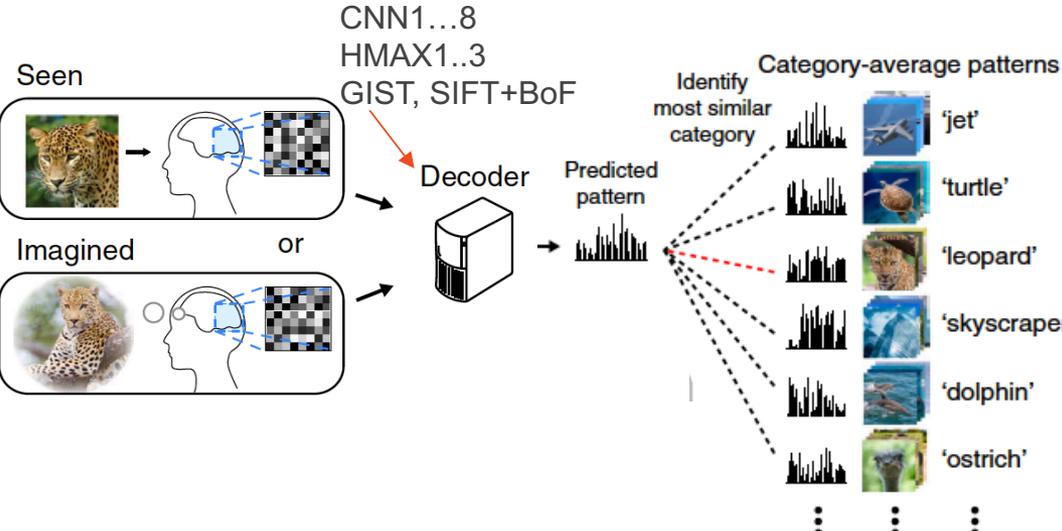
... Train: 1200 jim/150 ob cat (x24)
Test: 50 im/50 obj # cat (x35)
9 min each -> 9h15

1im/50 obj cat (x10)
Test: 1im/50 obj # cat
10 min each -> 3h33

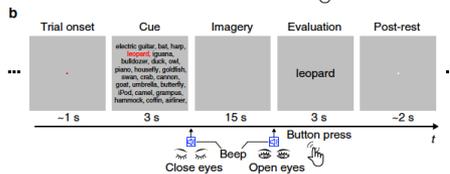


[Horikawa and Kamitani Nat Comm 2018]

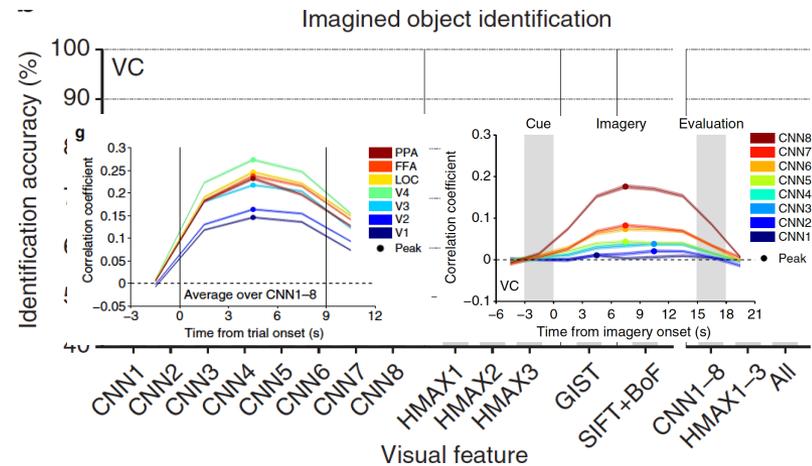
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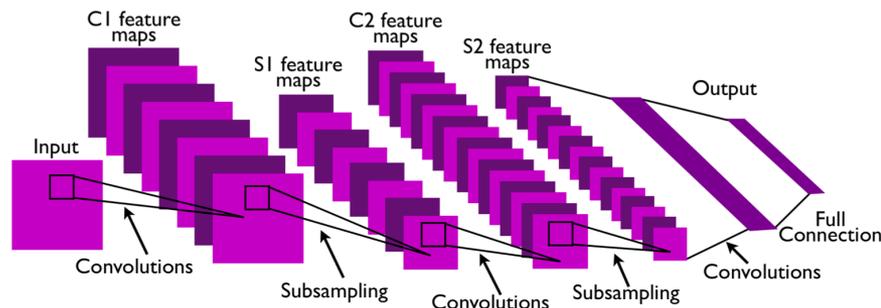


[Horikawa and Kamitani Nat Comm 2018]

Synthesis

- Isomorphism CNN layers – Visual areas up to IT)
 - Coherency of internal DNN & neural representation (invasive & non invasive data, natural to movie stimuli, ventral - dorsal)
 - Internal representation similarity (imagined scenes)
 - Encoding (stimulus -> brain representation)
 - Decoding (brain representation -> stimulus)

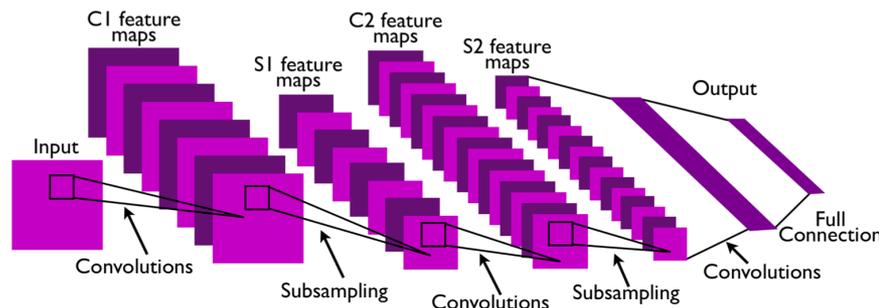
CNN as a model of the visual system ...



[Lecun et al 2010]

- ✓ Receptive field
- ✓ Hierarchical model
- ✓ Max pooling
- ✓ Normalisation
- ✓ Isomorphism layers-areas
- ✓ **Feedbacks**
- ✓ **Layer2layer conn.**
- ✓ **Nb layers / nb areas**
- ✓ **Eye mvt**
- ✓ Magnitude factor
- ✓ Color
- ✓ Metamer
- ✓ Attention
- ✓ Local vs Global
- ✓ Perspective effects
- ✓ Learning
- ✓ Illusion - Hallucinations
- ✓ Adversarial example
- ✓ Sensor Fusion

CNN as a model of the visual system ...

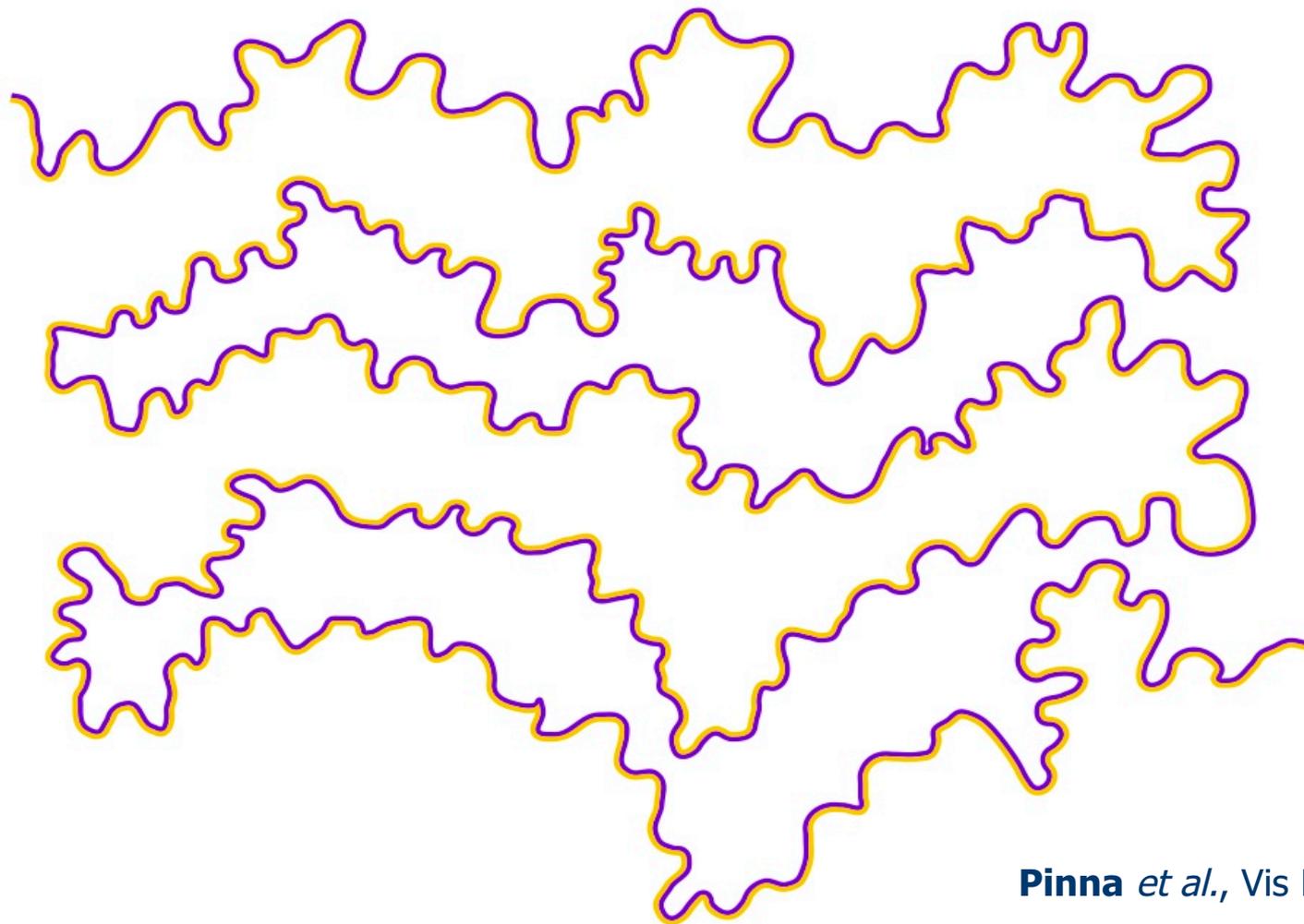


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CNN as a tool to probe specific situations

Water color effect

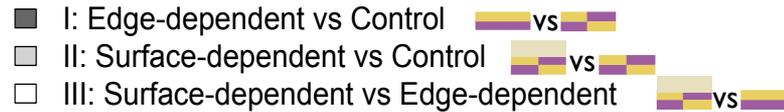
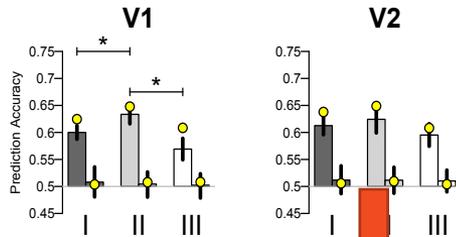


Pinna *et al.*, Vis Res. 2001.

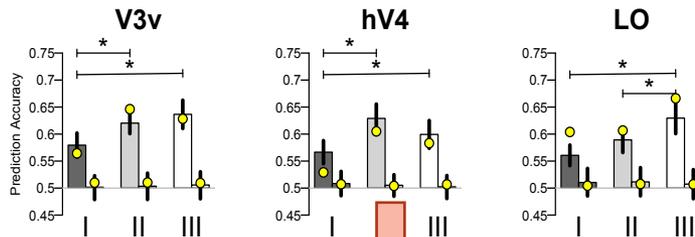
Results

Gérardin *et al. Neuroimage*, 2018

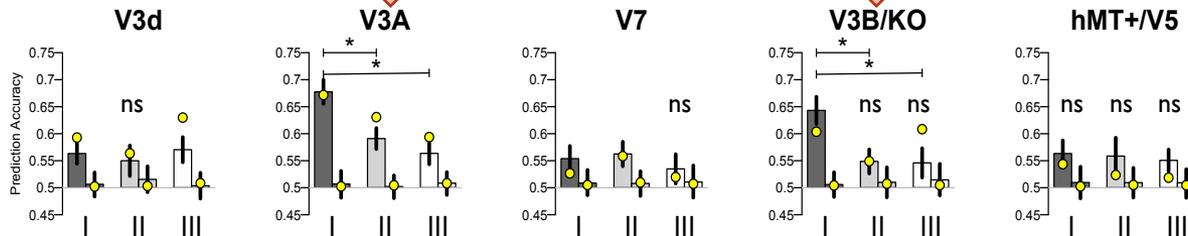
Retinotopic areas



Ventral visual areas



Dorsal visual areas



Multi-Voxel Pattern Analysis (MVPA) from fMRI data.

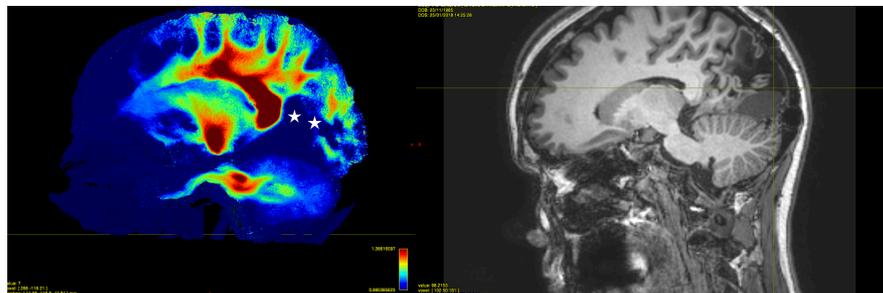
Conclusion

Gérardin *et al. Neuroimage*, 2018



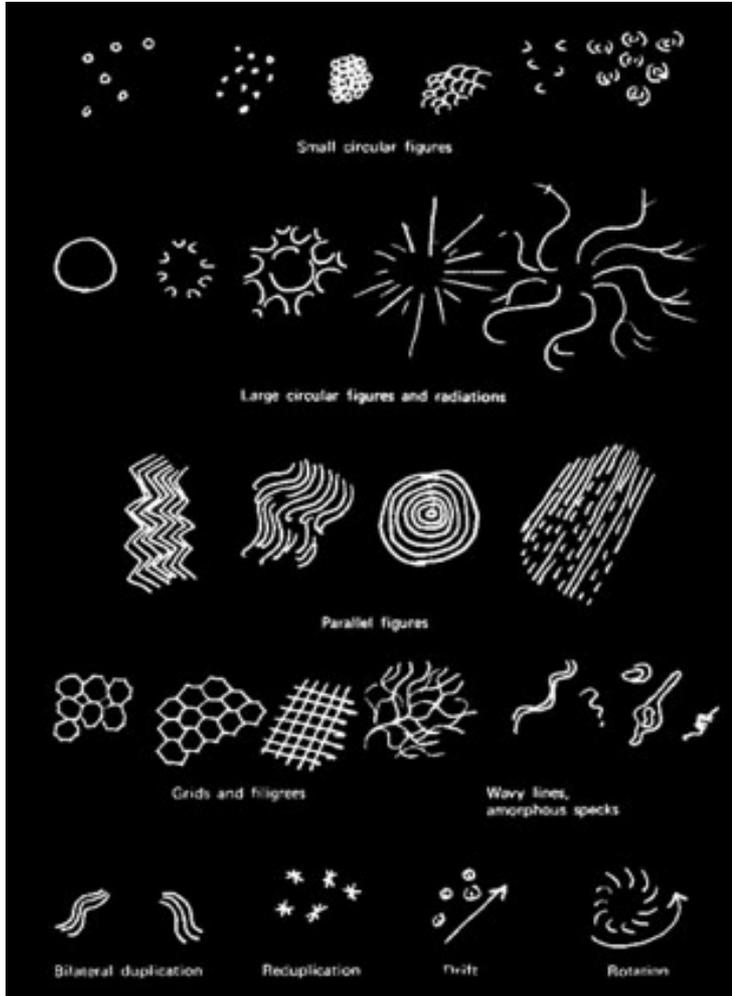
- Filling-in is best classified and best correlate with appearance by dorsal areas V3A & V3B/KO
- Uniform chromaticity by ventral areas hV4 & LO
- Feedback modulation from V3A to V1 and LO for filling-in
- Feedback from LO modulating V1 and V3A for uniform chromaticity

Visual Hallucinations



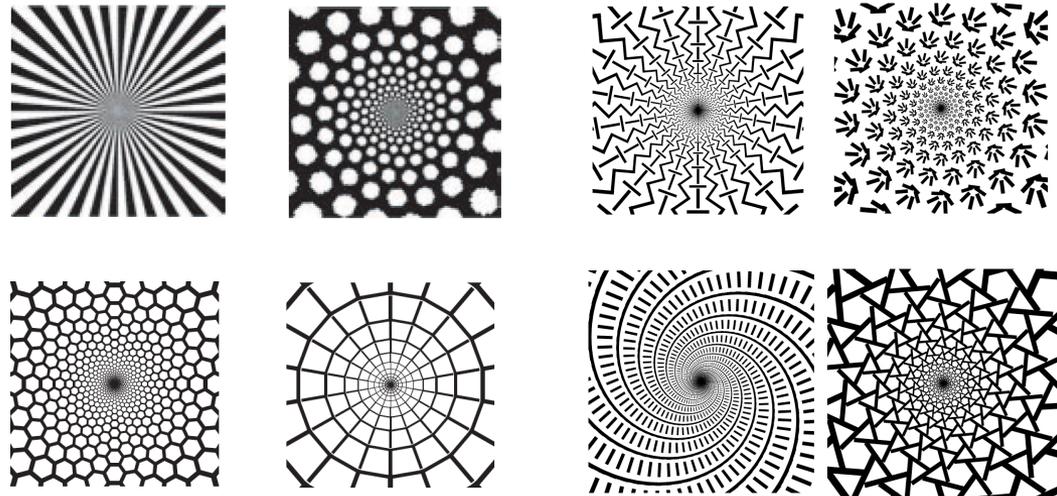
Passera et al HBM 2019

Hallucinations: recurrent patterns



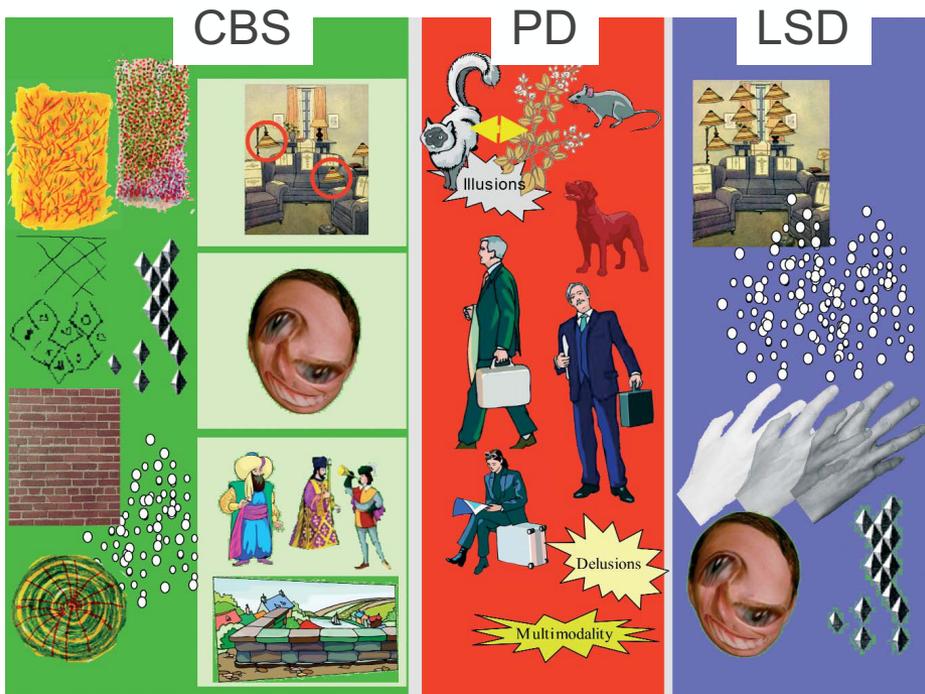
Klüver 1966

In V1



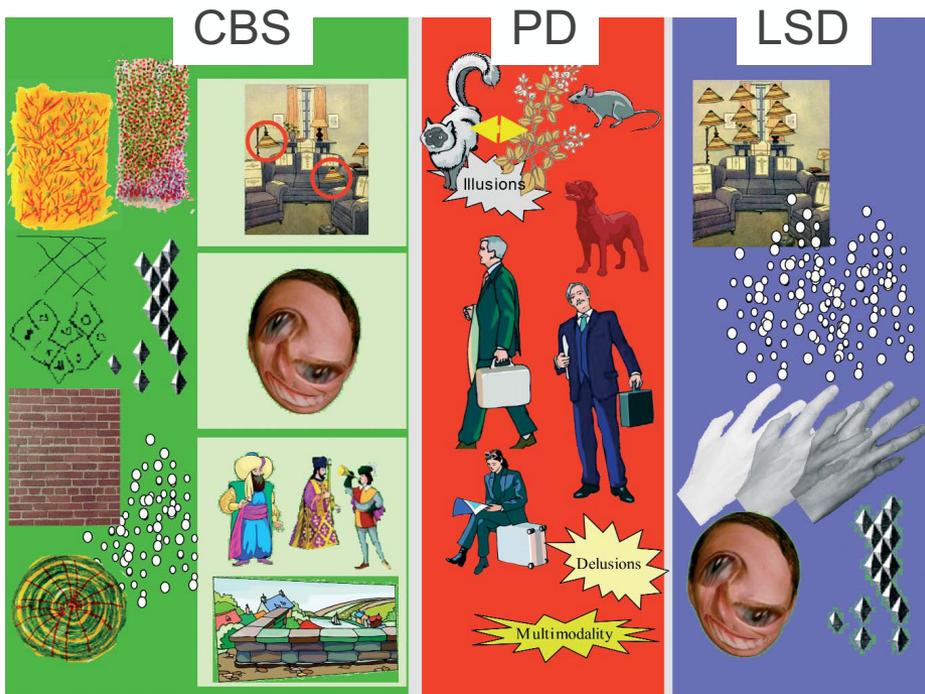
Bressloff et al. (Phil Trans R Soc Lond B 2001)

Hallucinations

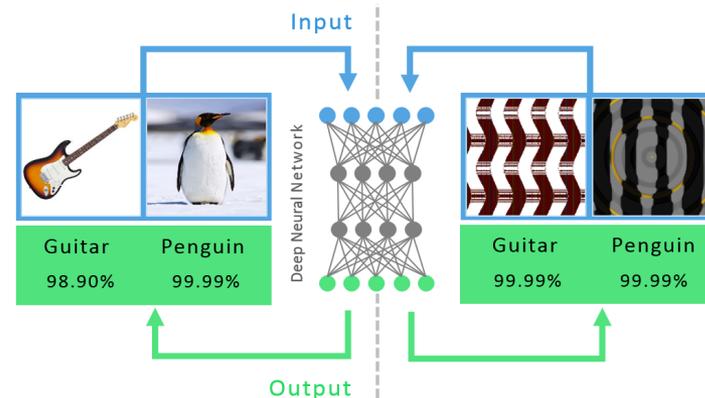


[Ffytche 2007 Dial Clin Neurosc]

Hallucinations



[Ffytche 2007 Dial Clin Neurosc]



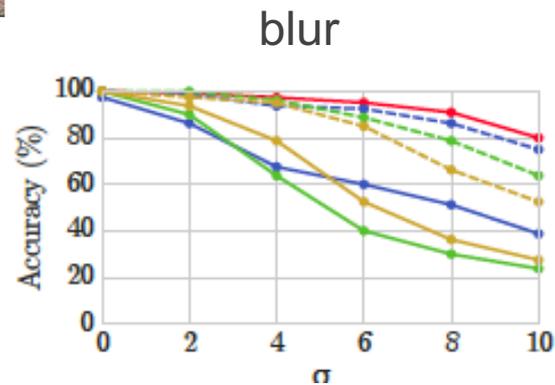
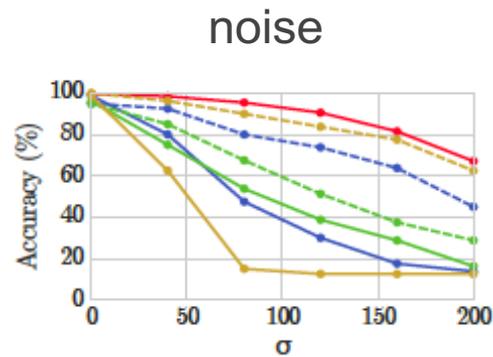
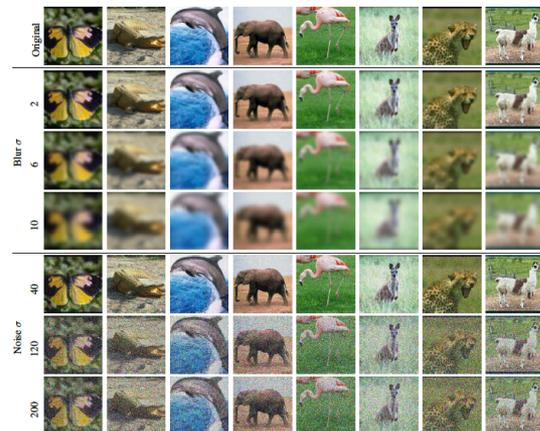
[Nguyen et al CVPR 2015]

Hallucinations



[DeepDream.com](https://www.deepdream.com)

Nobody is perfect ...

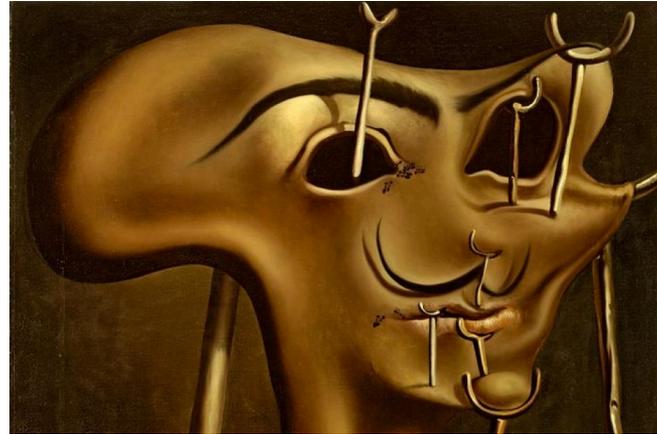


[Dodge and Karam ICCV 2017]

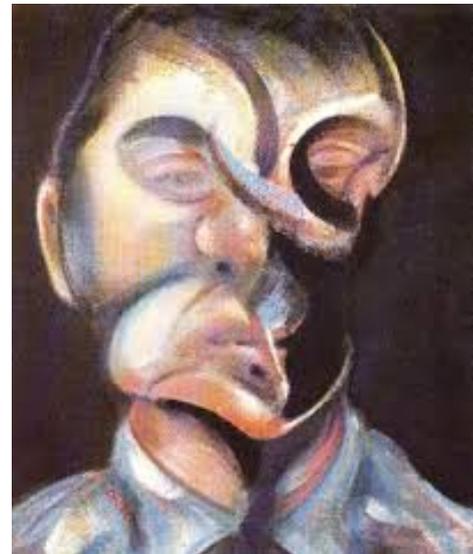
Nobody is perfect ...



[Arcimboldo 1573]



[Dali 1941]



[Bacon 1972]

Biological plausibility

NATURE VOL. 337 12 JANUARY 1989

COMMENTARY

129

The recent excitement about neural networks

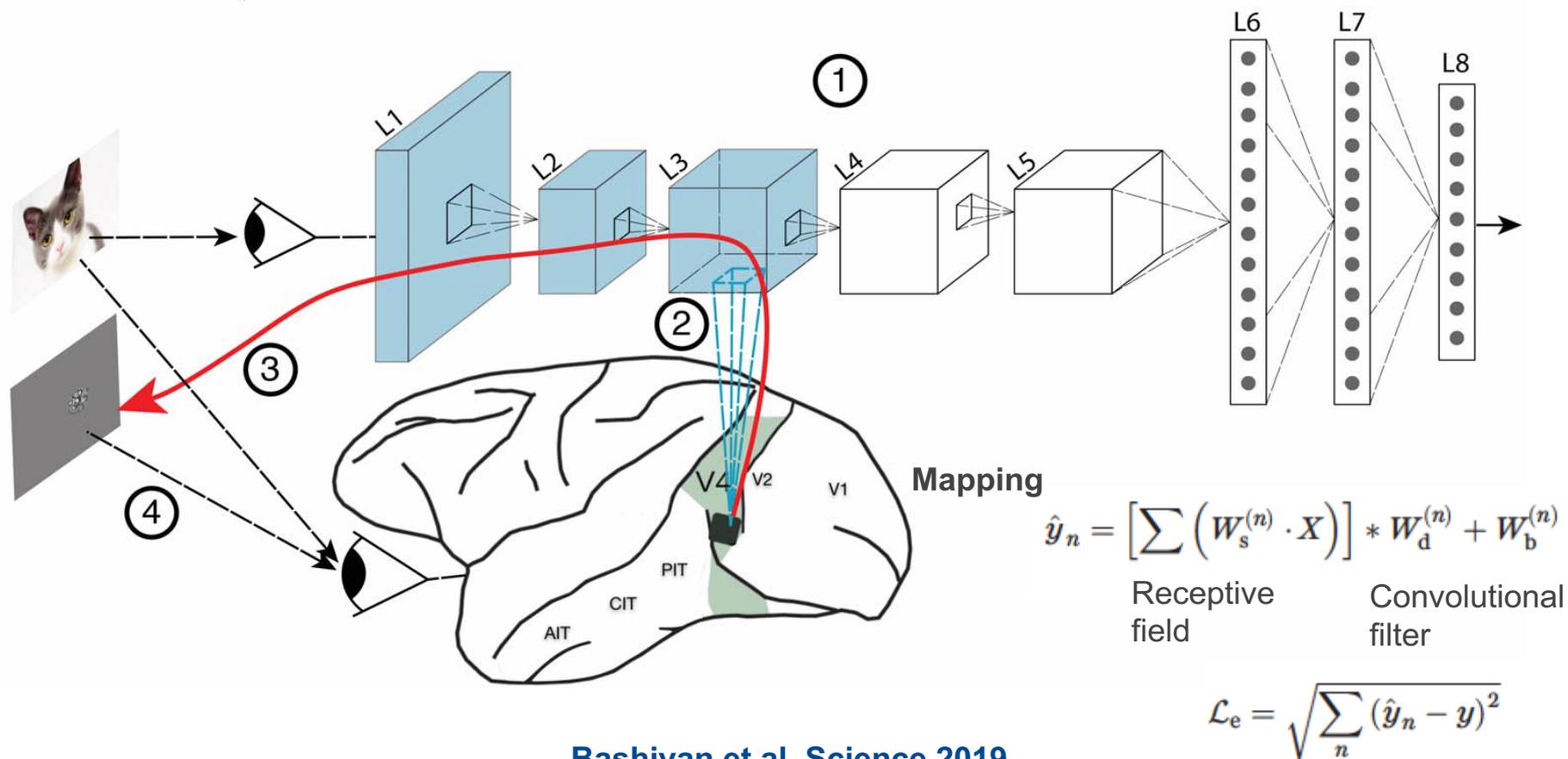
Francis Crick

The remarkable properties of some recent computer algorithms for neural networks seemed to promise a fresh approach to understanding the computational properties of the brain. Unfortunately most of these neural nets are unrealistic in important respects.

« BP model is not a model of a brain process » Grossberg 1987 Cog Sc

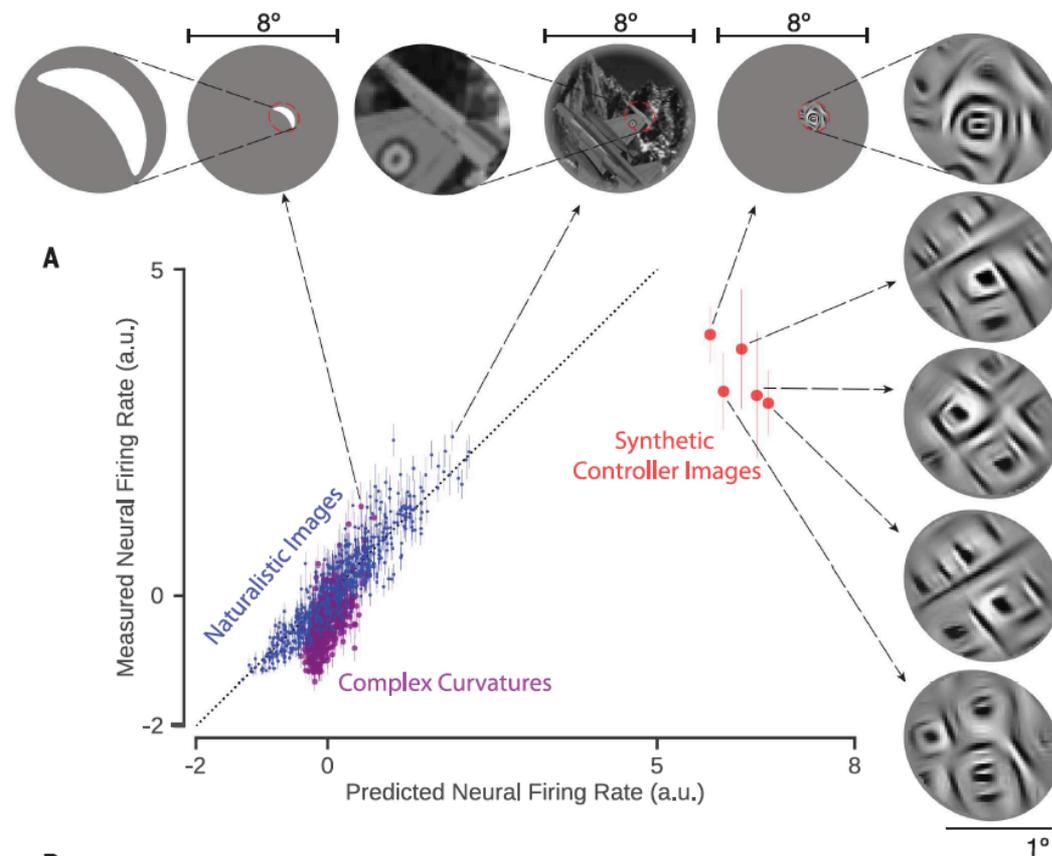
Predicting behavior of visual neurons

To what extent are predictive deep learning models of neural responses useful for generating experimental hypotheses?



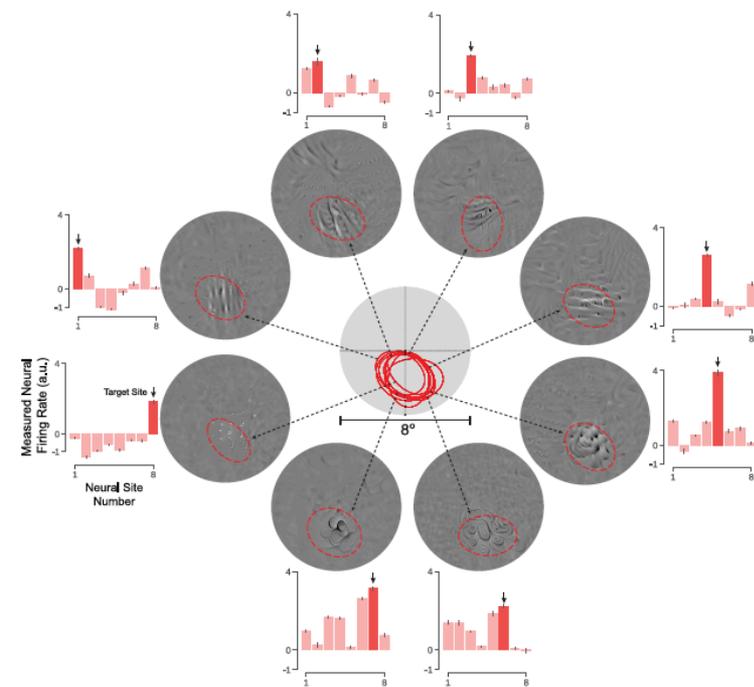
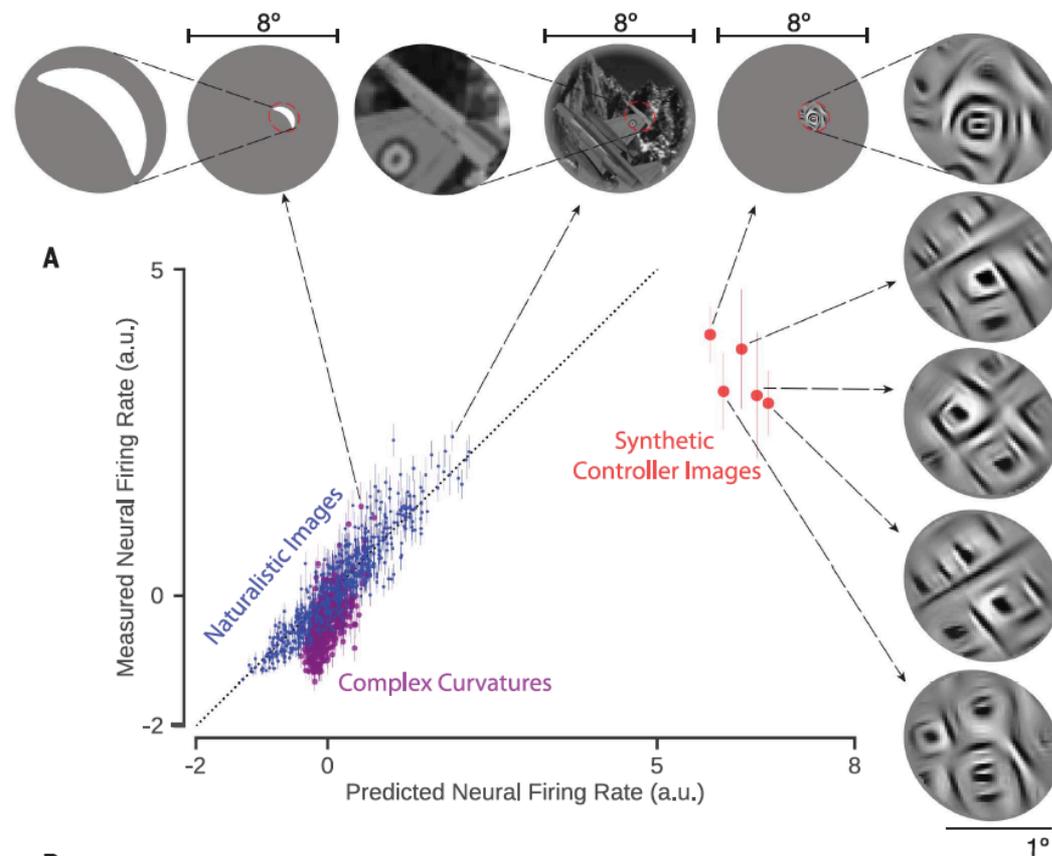
Bashivan et al. Science 2019

Predicting behavior of visual neurons



R

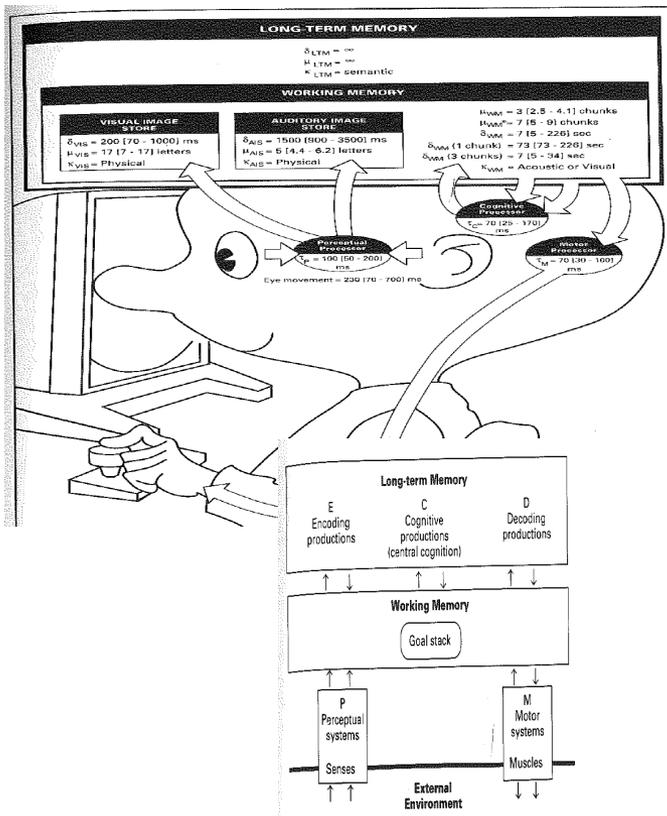
Predicting behavior of visual neurons



Control of each neural site
In V4

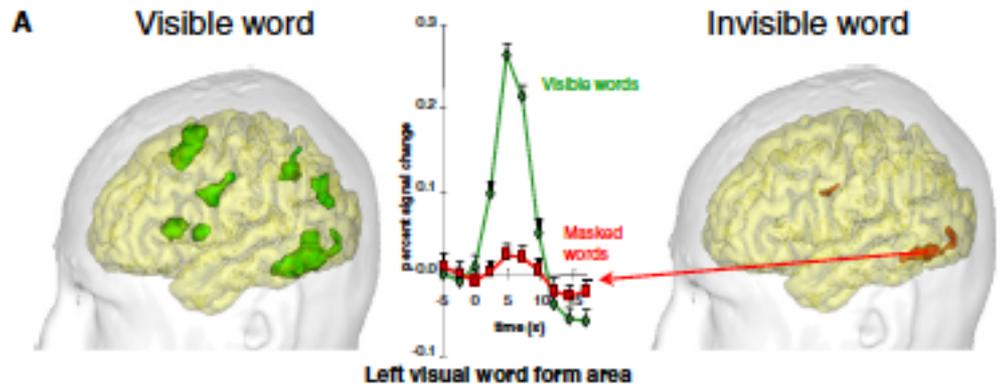
Consciousness model

Soar:
[Newell 1983, 92]



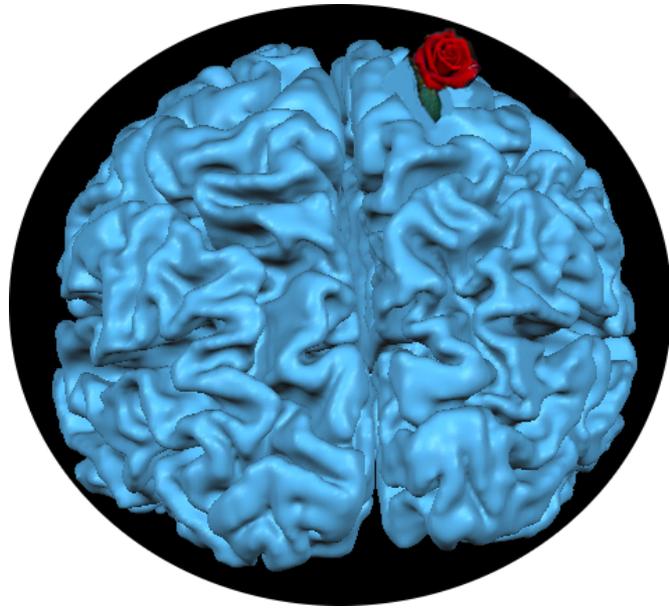
Global workspace theory
[Baars 1988, 97, 2002]

Global ignition
[Dehaene 2003]



[Dehaene and Changeux Neuron 2011]

CARMEN : Conscience Attention Représentation Mentale



La Conscience dans tous ses états

14th November 2019



NeuroCoG

Univ. Grenoble Alpes

Casting

@GIN

E. Barbier
T. Christen
M. Dojat
B. Lemasson
J. Warnking

C. Acquitter
F. Boux
L. Broche
C. Brossard
V. Kmetzsch
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