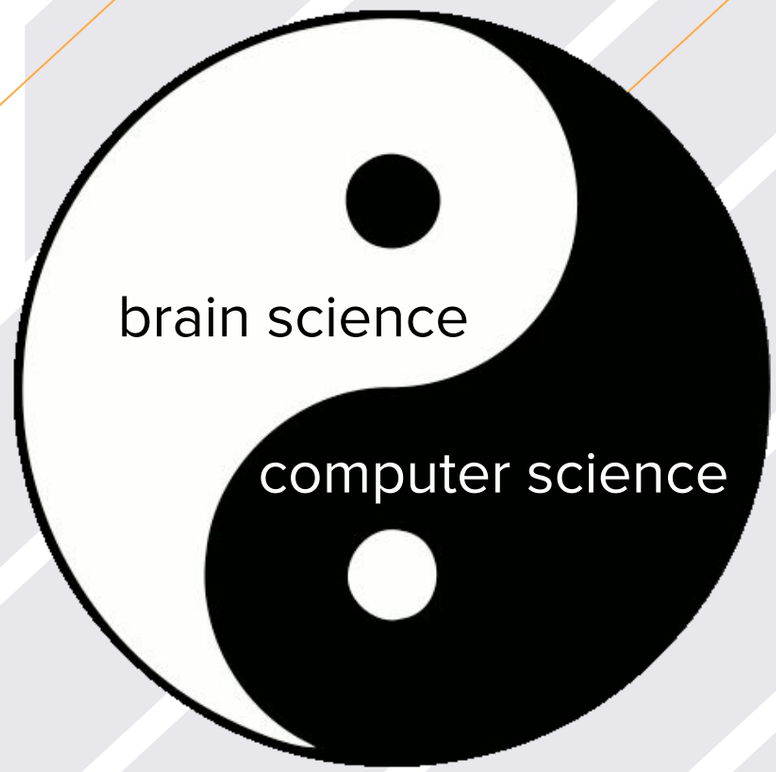
Can brain science help computer science and vice-versa?



Thomas Serre

Cognitive Linguistic & Psychological Sciences
Carney Institute for Brain Science
Center for Computation and Visualization
Brown University

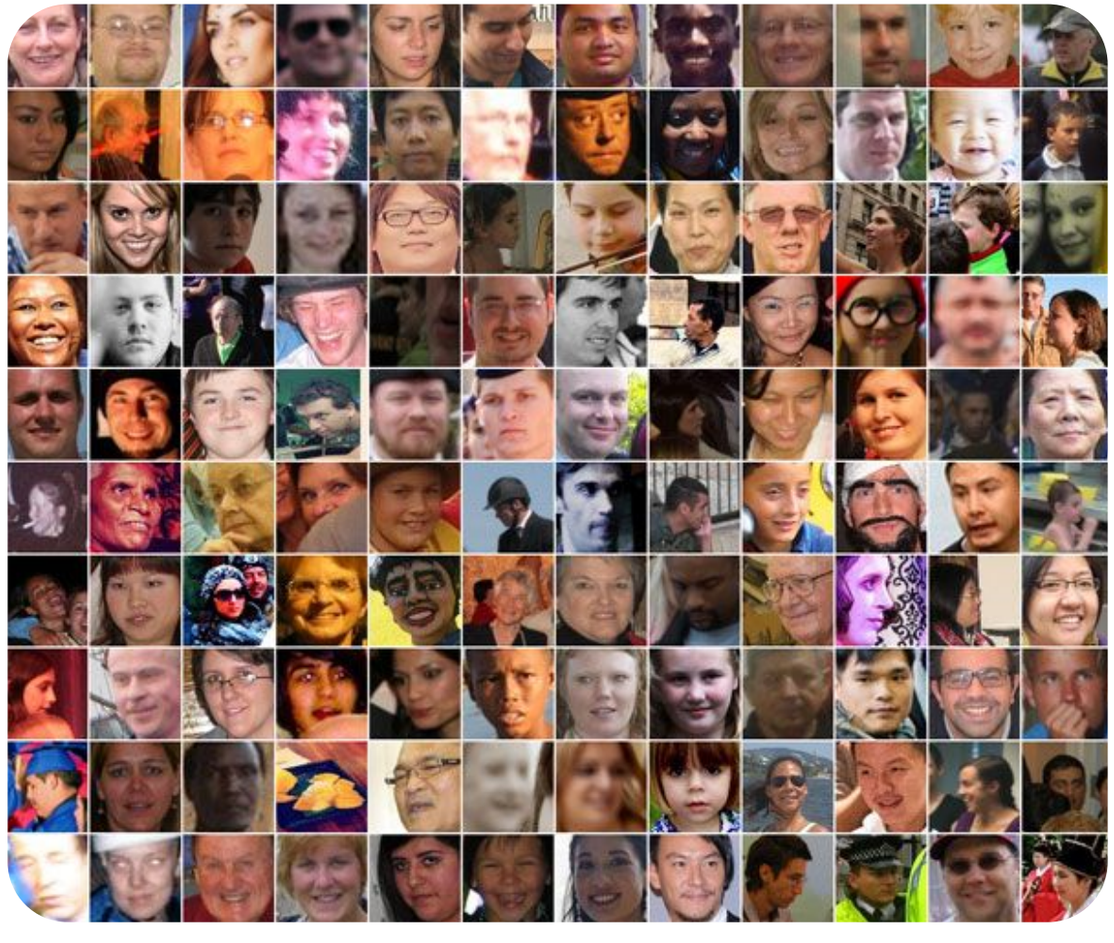
Deep nets:

The good

“Superhuman” capabilities

Object recognition (ImageNet)

face recognition (MegaFace)



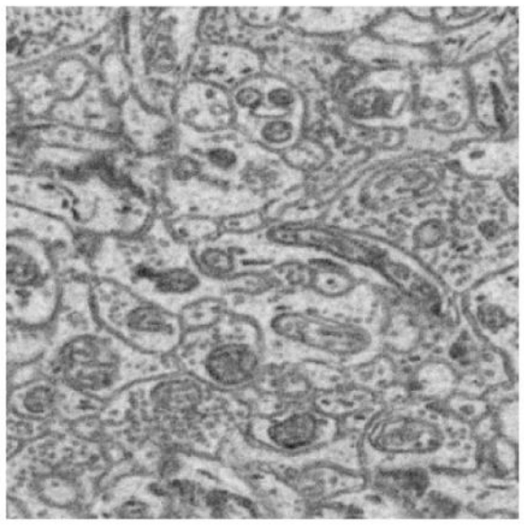
Russakovsky et al 2015, Nech & Kemelmacher-Shlizerman 2017; Philips et al 2018

Deep nets:

The good

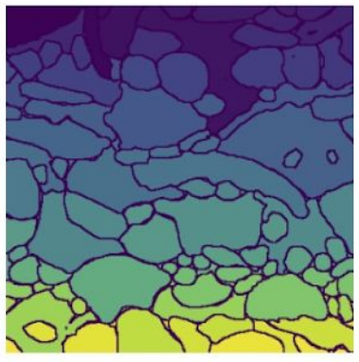
“Superhuman” capabilities

Neural tissue segmentation (connectomics)



Volume

Membrane



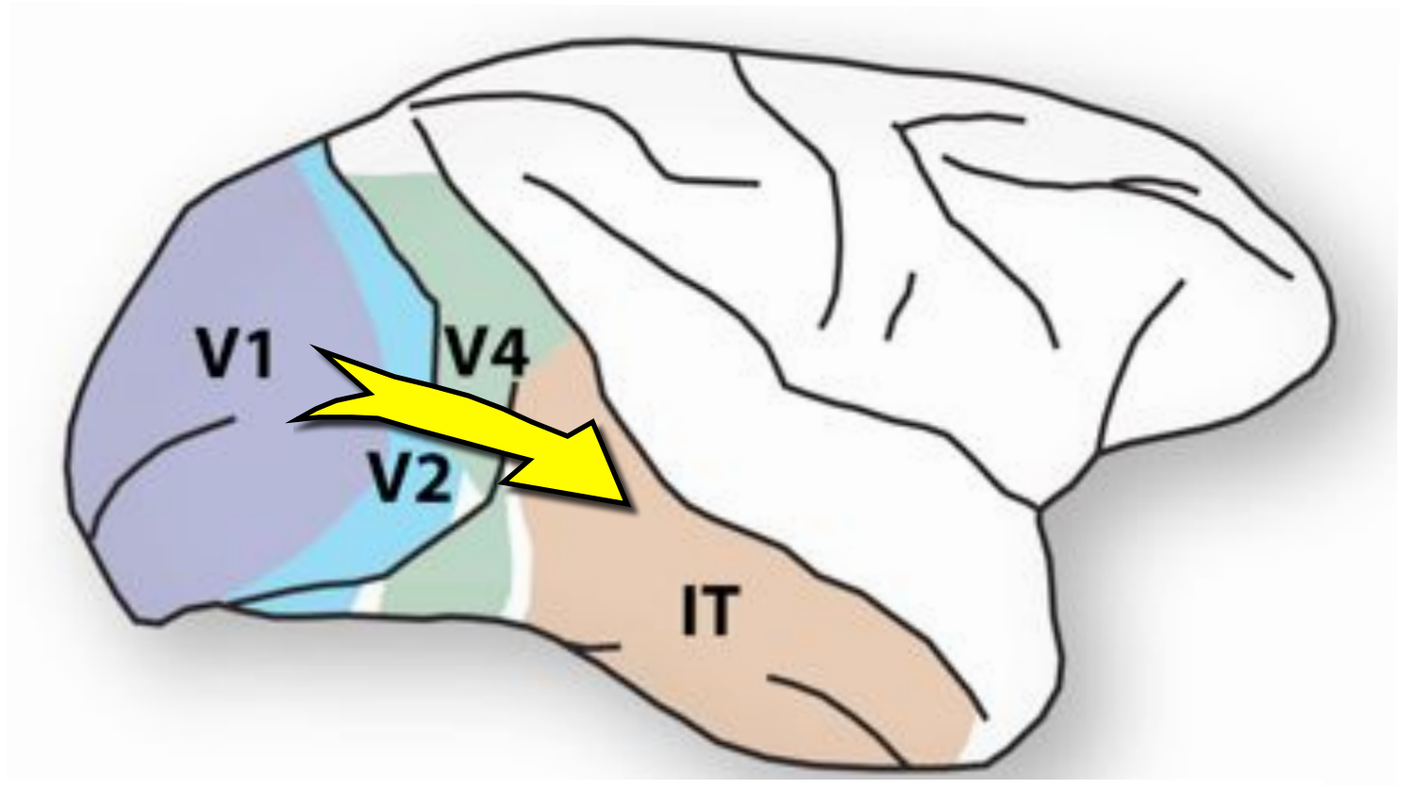
Segments

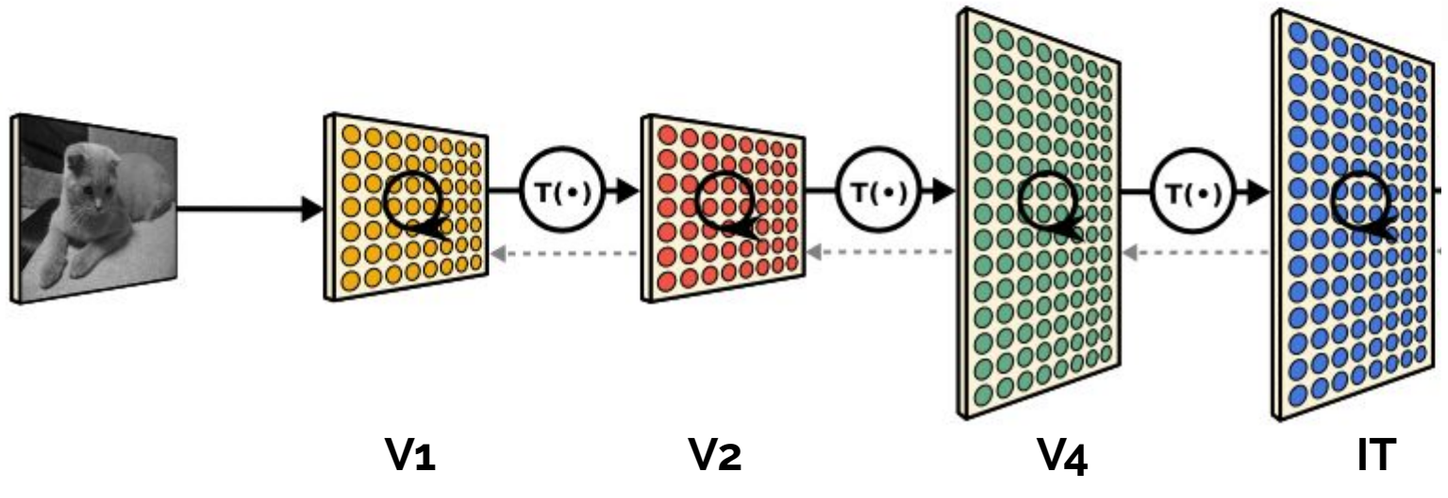
Lee et al 2017; Januszewski et al 2018

Deep nets:

The good

Feedforward sweep, passive viewing





See Serre Annual Review of Vision 2019

Deep nets:
The bad

Systematic differences w|humans

- Shape similarity judgments
  (Kubilius et al. 2016, Pramod & Arun 2016, Erdogan & Jacobs 2017, Baker et al 2018)
- Illusory contours
  (Kellman et al 2017)
- Sensitivity to image perturbations + temporal changes to image sequences
  (Berardino et al 2017, Hénaff et al 2019)
- **Leverage different visual features**
  (Linsley et al 2017, 2019)

See Serre Ann Rev Vision 2019

Deep nets:

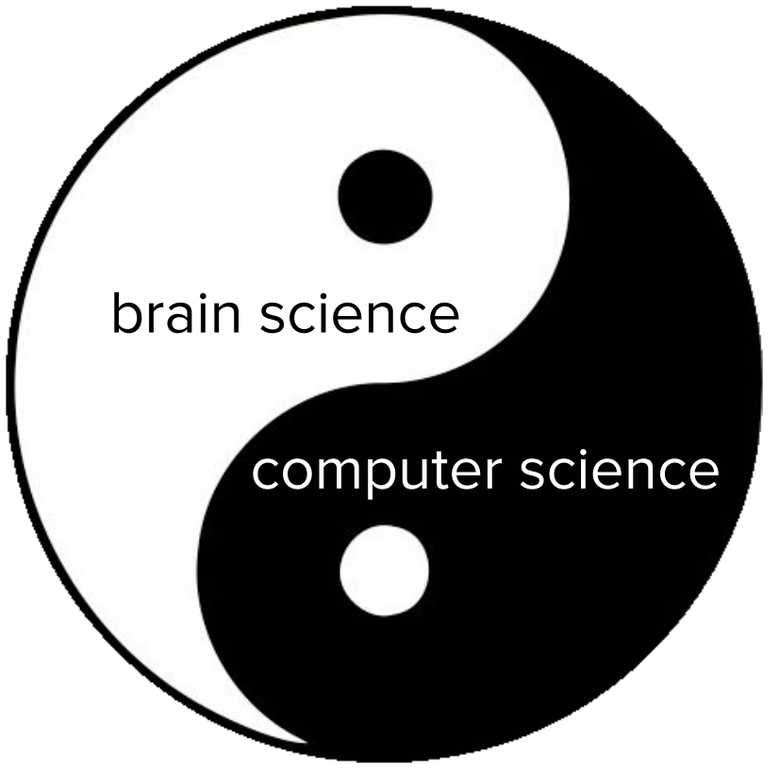
The uggly

“Out-of-distribution” sample

- DNNs shatter ImageNet
  (Zhang et al 2017)
- DNNs overfit to (excessively) re-used test sets
  (Recht et al 2019)
- DNNs do not generalize to out-of-distribution samples, e.g.:
  - out-of-context objects, clutter and occluders
    (Saleh et al 2016, Rosenfeld et al 2018, Tang et al 2018, Wang et al 2018)
  - subtle changes in the type of noise used for train vs. test
    (Gheiros et al 2018)
  - **connectomics: different tissues used for train vs. test**
    (Linsley et al 2018)
  - **limited abstraction beyond training data in vis reasoning**
    (Kim et al 2018)

See Serre Ann Rev Vision 2019

Neuroscience
as inspiration



- Feedback mechanisms
  - Attention
  - Grouping
  - Oscillations
  - etc
- Memory (working, episodic, etc)

Learning
to attend

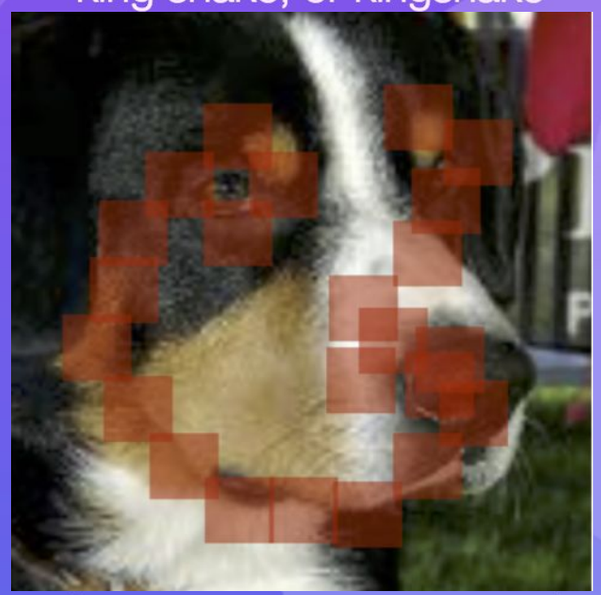
clickme Your user name is: fancy couple What's the point? Instruc

Help the AI recognize this image before time runs out!

The top-5 scoring players by Sun Apr 23 2017 12:00:00 EST win a gift card! See the Scoreboard tab for details.

Click and then brush with your mouse to reveal image parts best describing a:

king snake, or kingsnake



Skip this image: it has a strange label or poor quality.

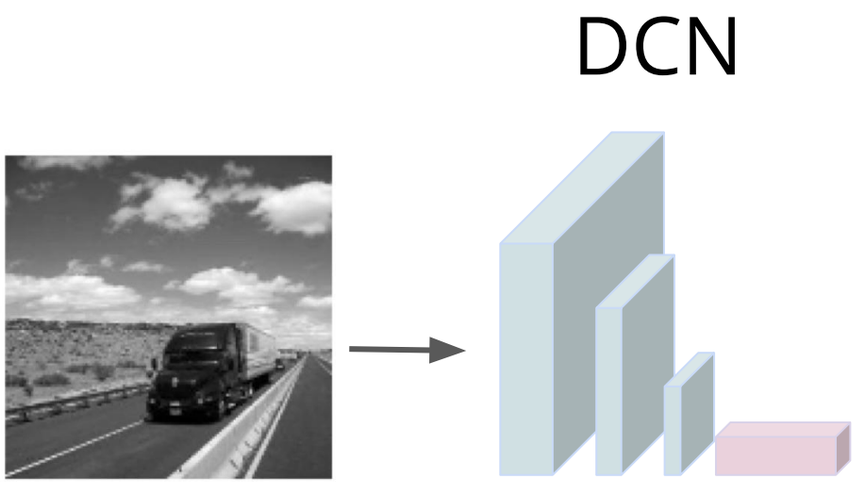
Your score: 0.00 | High score: 113950.85

Our AI will evolve after this many images are played:

http://www.clickme.ai

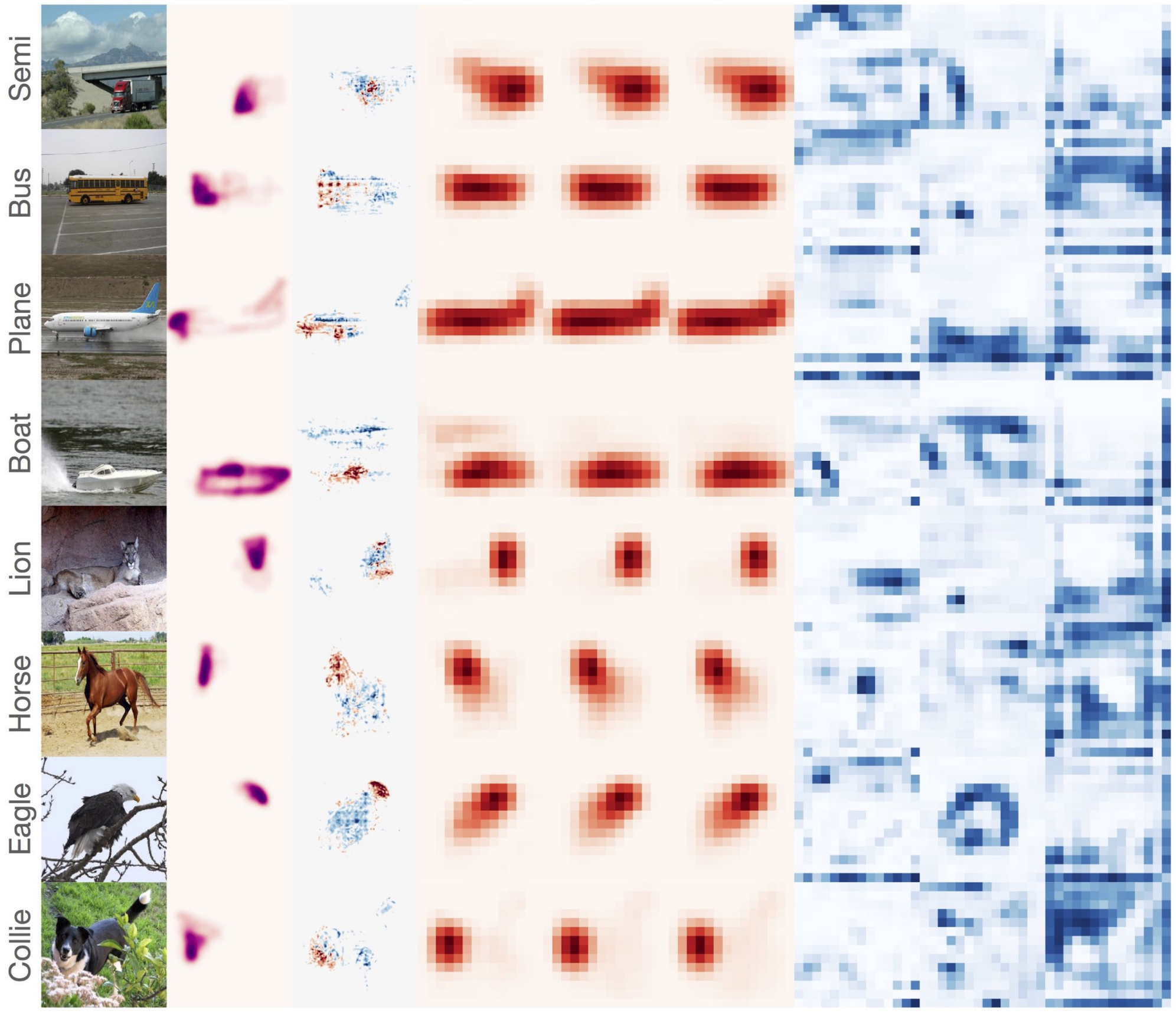
Linsley Schiebler Eberhardt Serre ICLR 2019

Learning
to attend



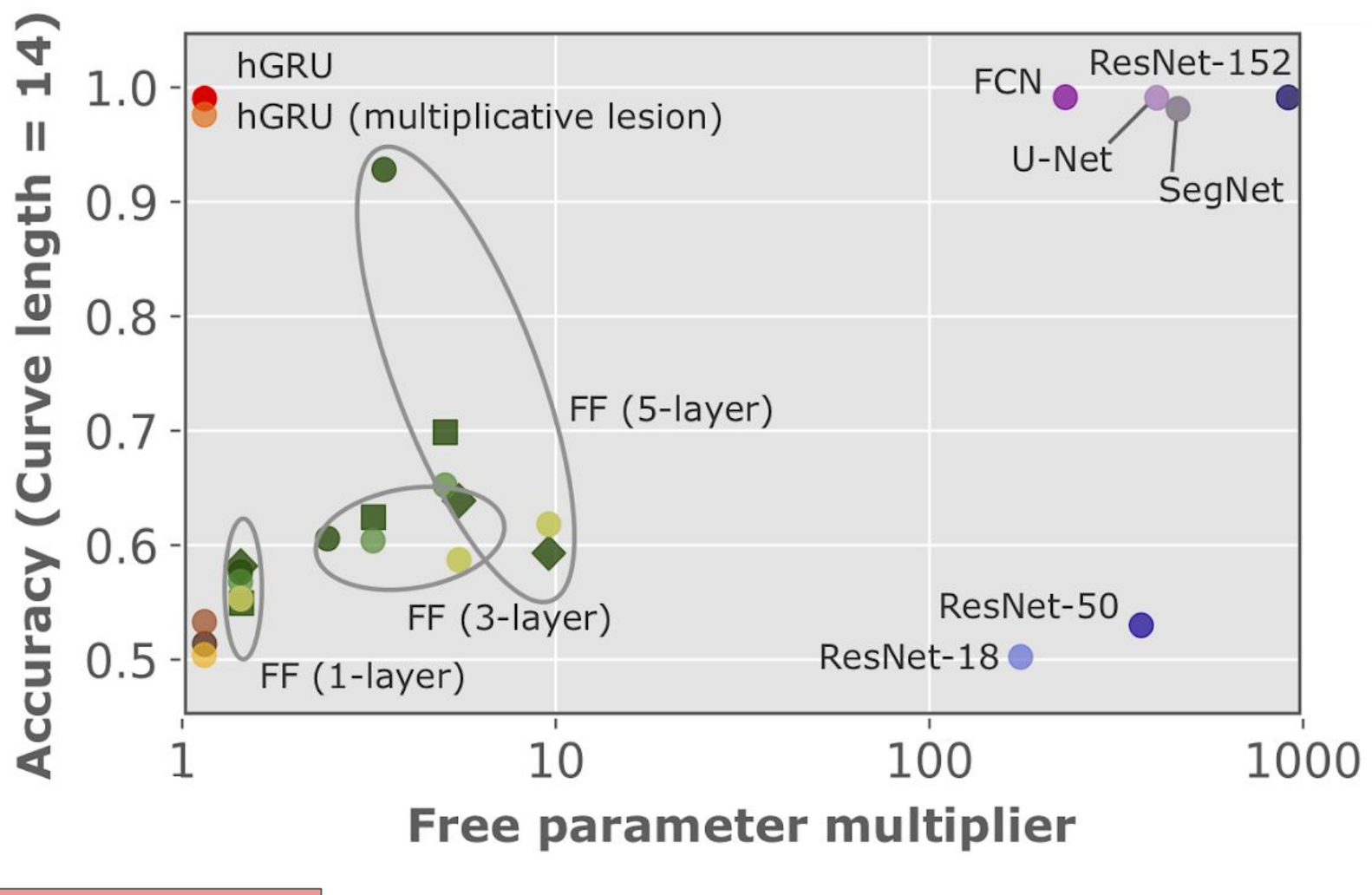
	top-1 err	top-5 err	maps
SE-ResNet-50	66.17	42.48	64.36**
ResNet-50	63.68	40.65	43.61
GALA-ResNet-50 no ClickMe	53.90	31.04	64.21**
GALA-ResNet-50 w/ ClickMe	**49.29**	**27.73**	**88.56****

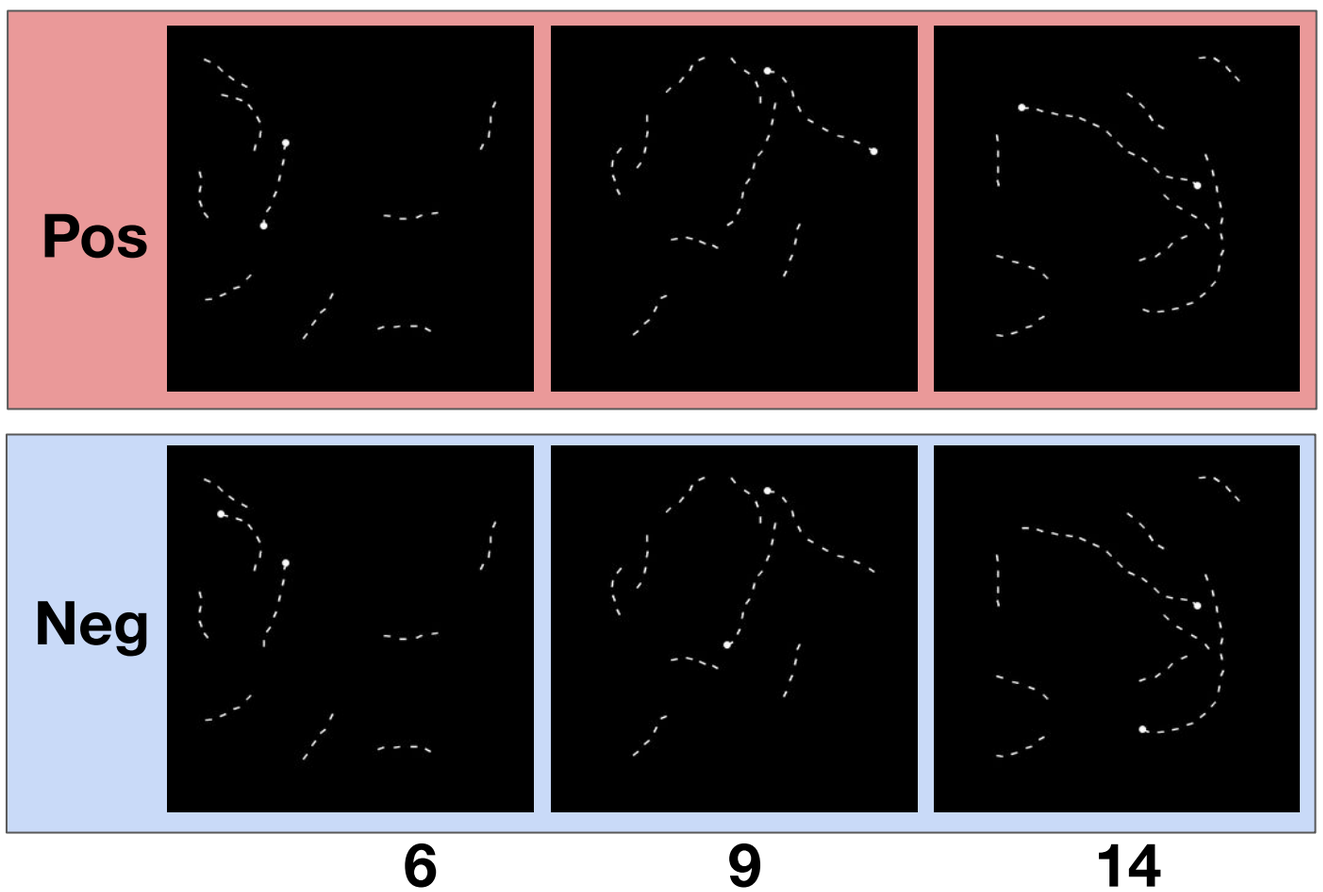
Linsley Schiebler Eberhardt Serre ICLR 2019



Linsley Schiebler Eberhardt Serre ICLR 2019

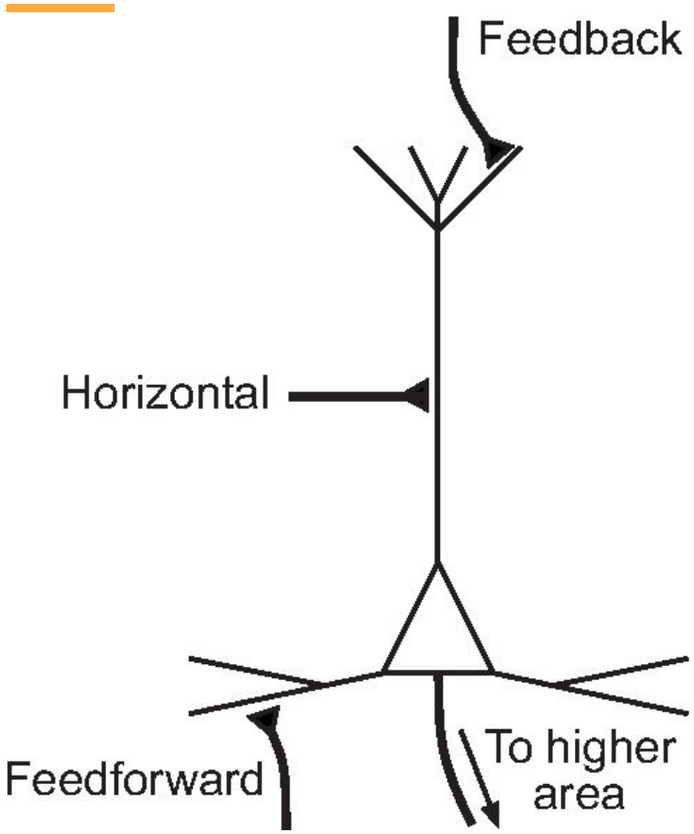
Learning
to group

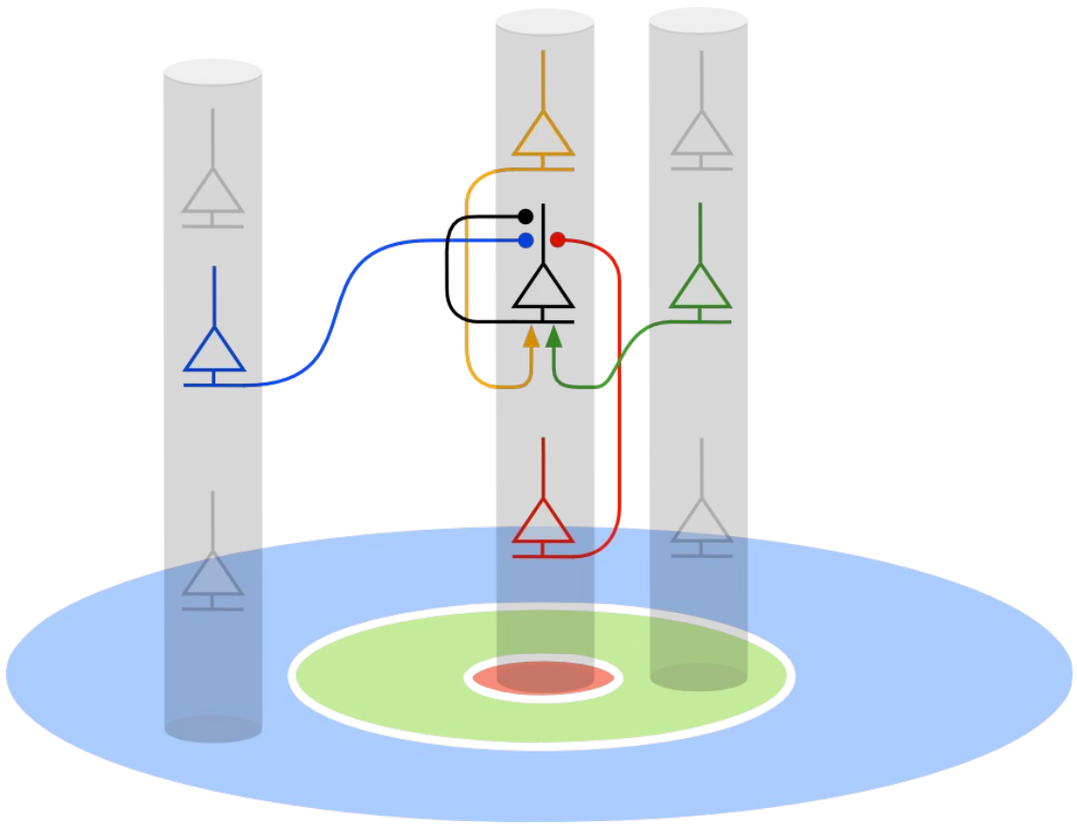




Linsley Kim Veerabadran Windolf & Serre NeurIPS 2018

Highly-recurrent
network model





$$C^{(1)}_{xyk} = \left(\mathbf{W}^I * \mathbf{H}^{(2)}\right)_{xyk}$$

$$C^{(2)}_{xyk} = \left(\mathbf{W}^E * \mathbf{H}^{(1)}\right)_{xyk}$$

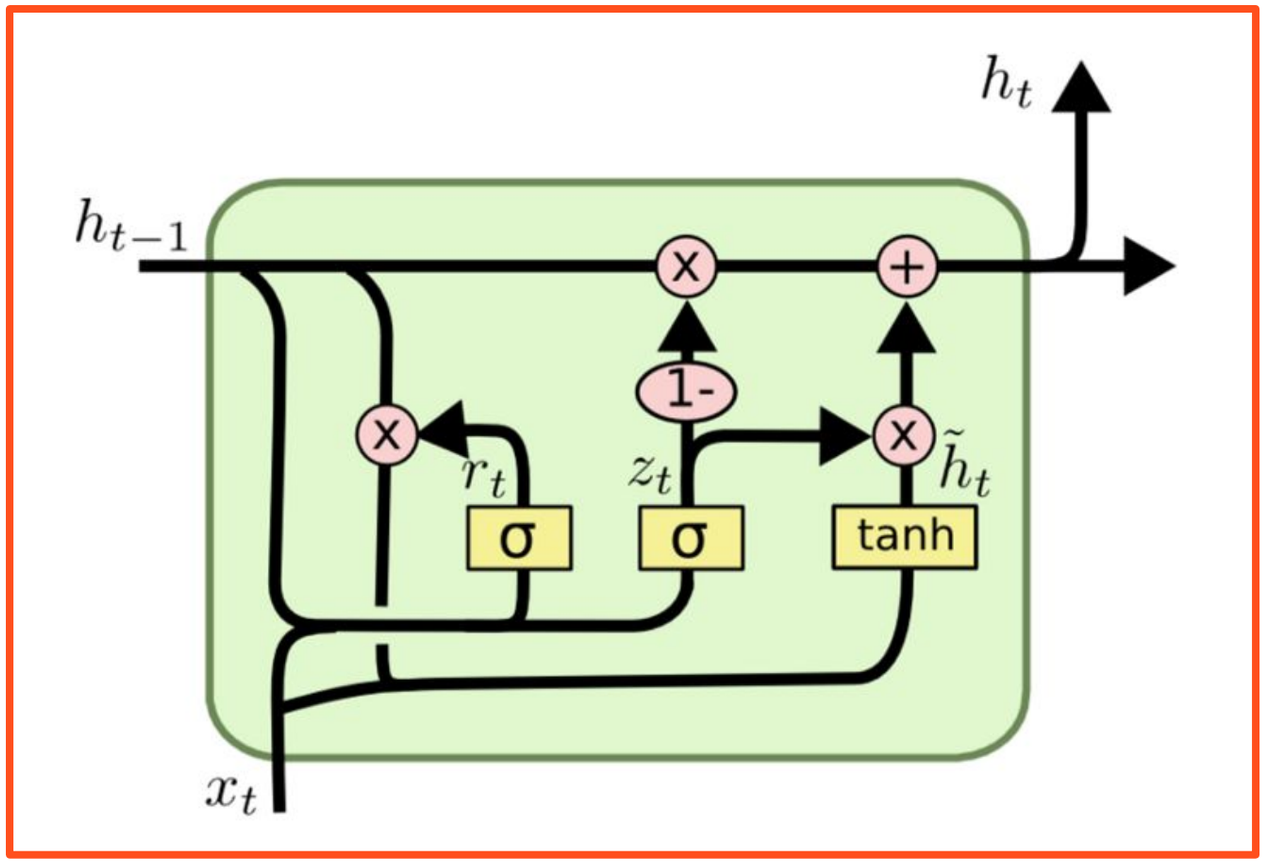
$$\eta \dot{H}^{(1)}_{xyk} + \epsilon^2 H^{(1)}_{xyk} = \left[\xi X_{xyk} - \left(\alpha H^{(1)}_{xyk} + \mu\right) C^{(1)}_{xyk}\right]_+$$

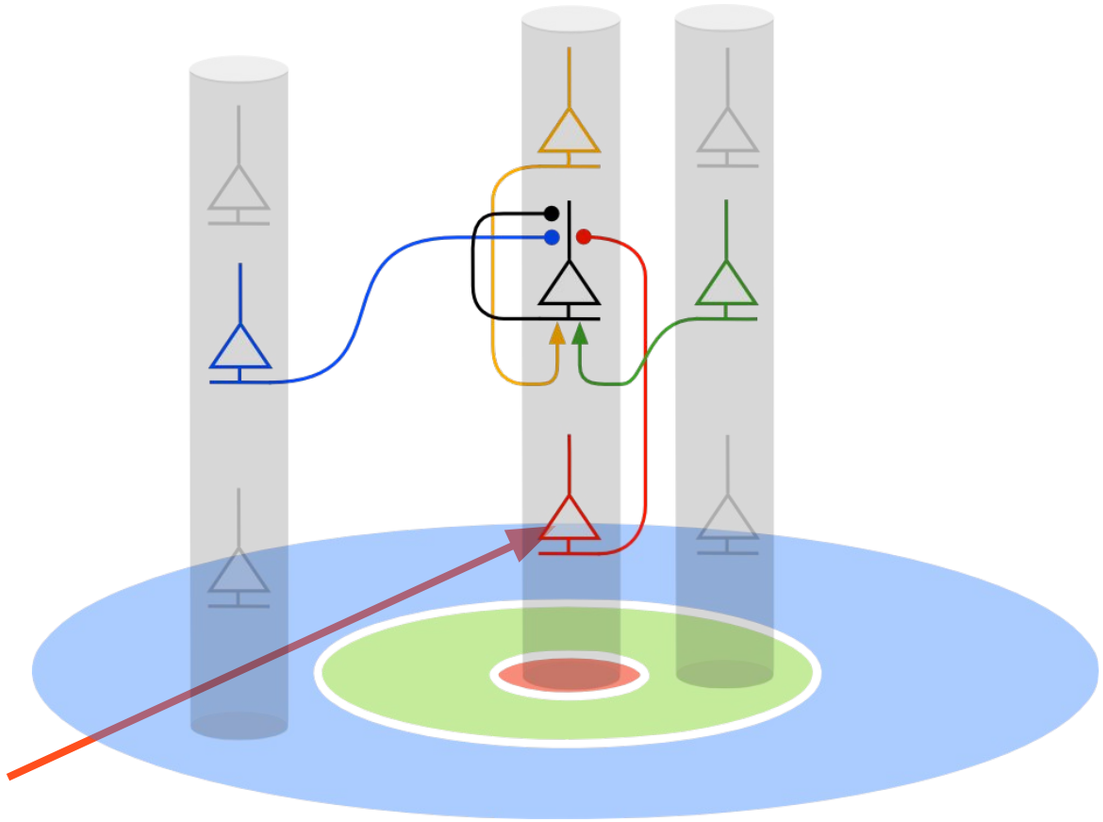
$$\tau \dot{H}^{(2)}_{xyk} + \sigma^2 H^{(2)}_{xyk} = \left[\gamma C^{(2)}_{xyk}\right]_+ .$$

Mely Linsley & Serre Psych Review 2018

From a neural circuit...

... to an ML module

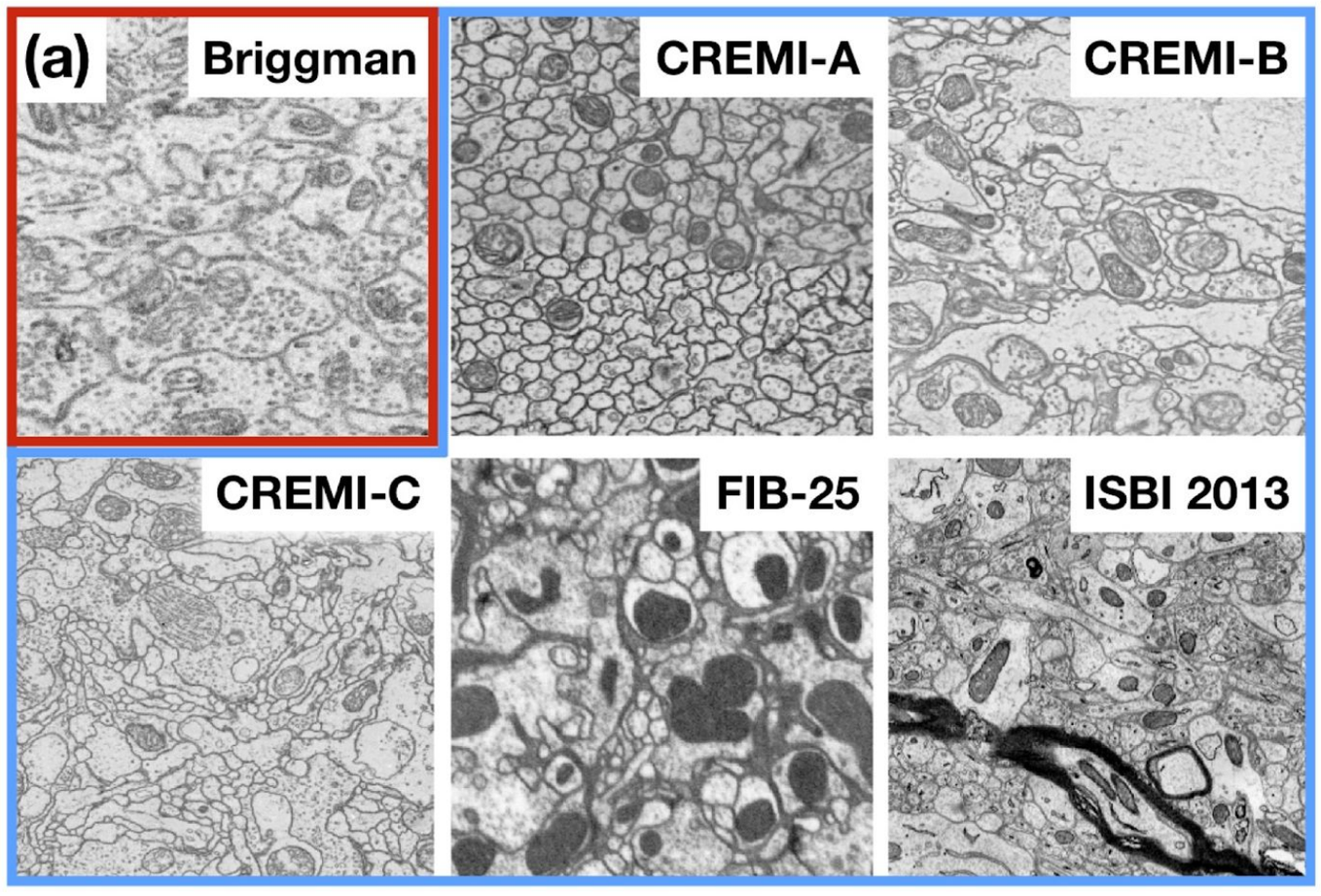




Linsley Kim Veerabadran Windolf & Serre NeurIPS 2018

Feedback GRU
(fGRU)

	mAP	Parameters
FF-Control	0.63	60K
fGRU-1	0.74	45K
fGRU-2	0.77	50K
3D U-Net [24]	**0.78**	1.4M

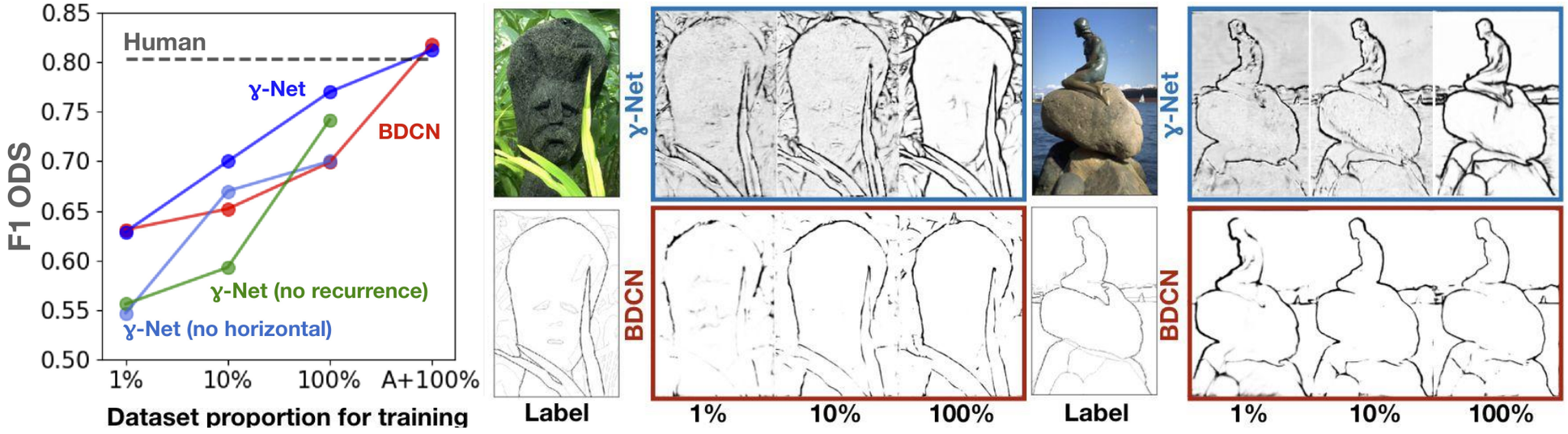


Linsley Kim & Serre arXiv:1811.11356 2018

Feedback GRU

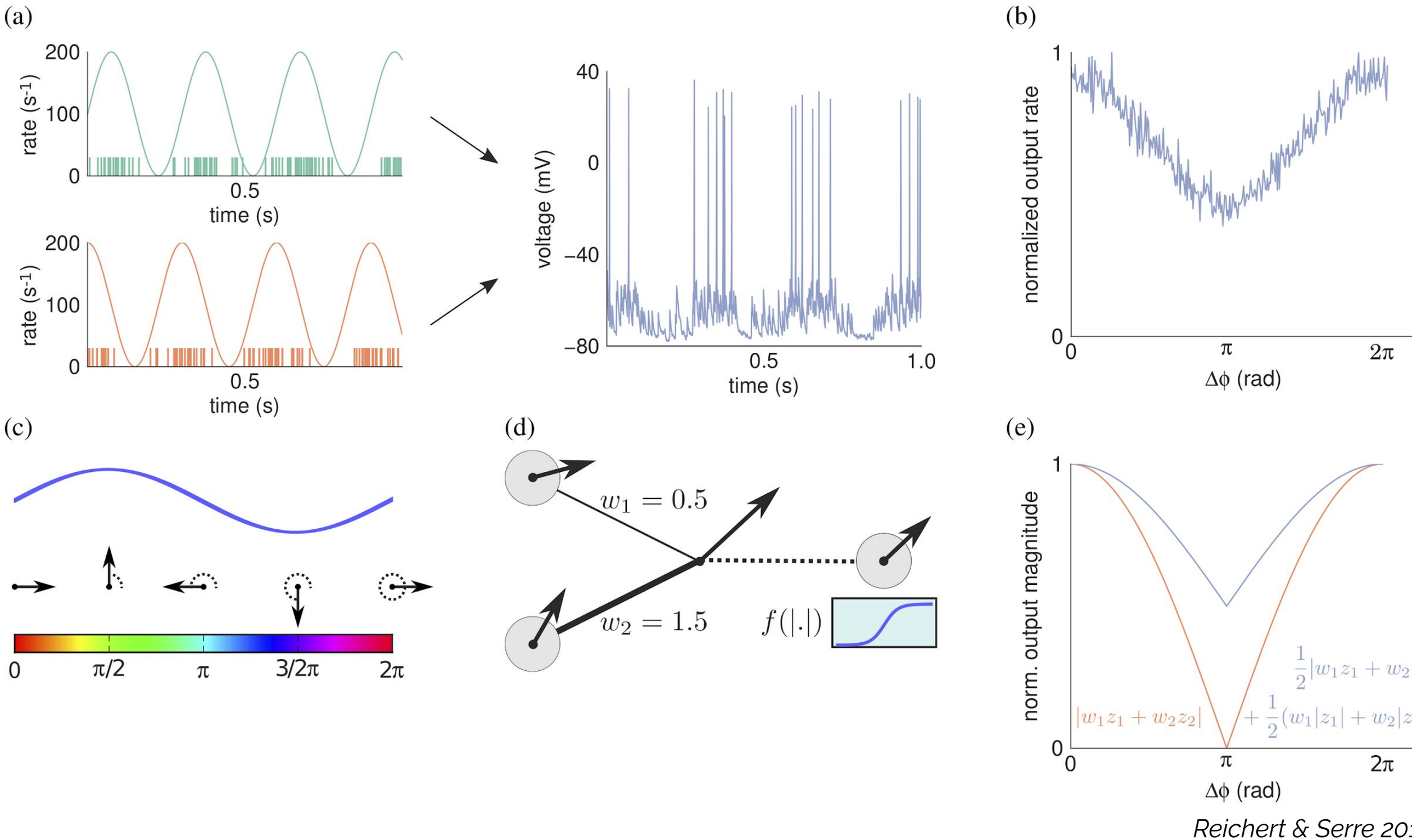
(fGRU)

Linsley Kim* & Serre arXiv 2019*



Need help to develop BPTT-alternatives which make more efficient use of memory!

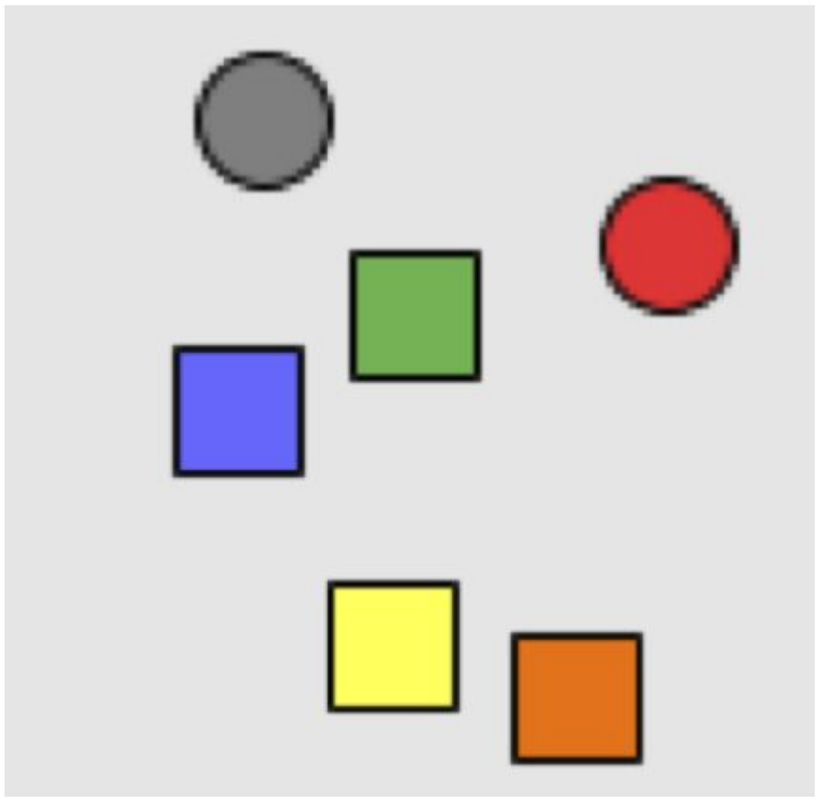
Computing w|
oscillations

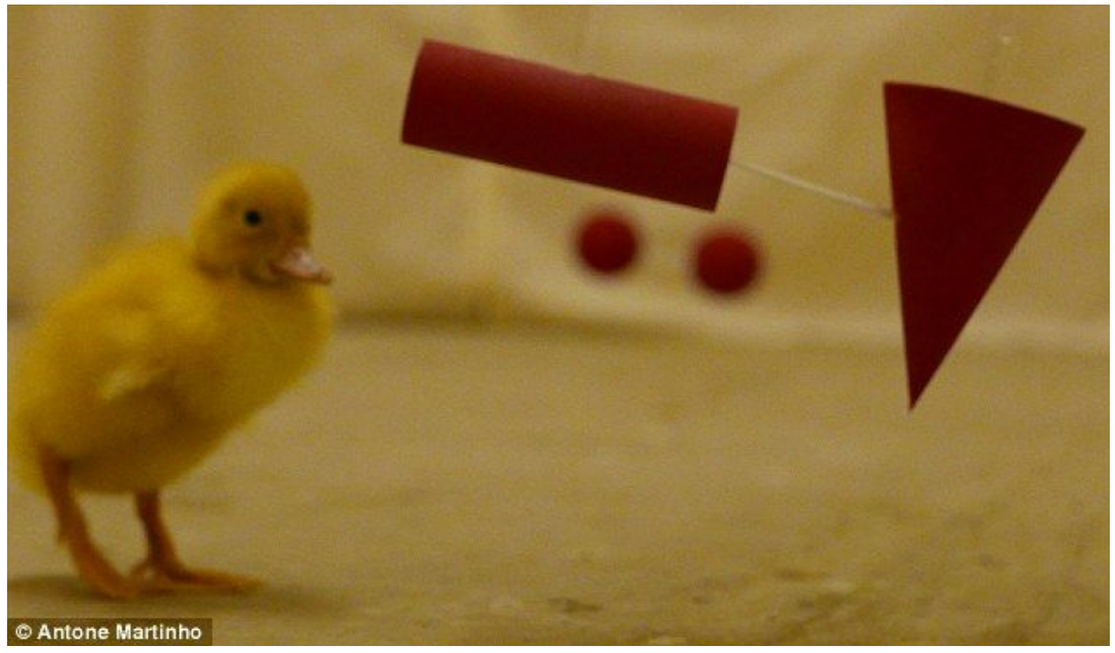


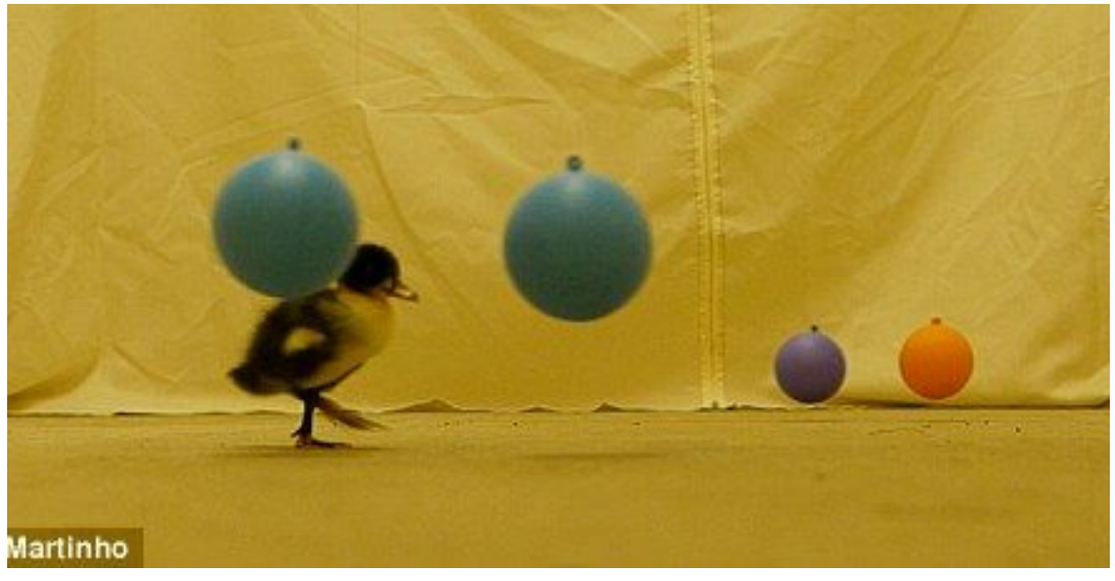
Reichert & Serre 2014

Visual
reasoning

Sort-of-CLEVR dataset
(Santoro et al 2017)



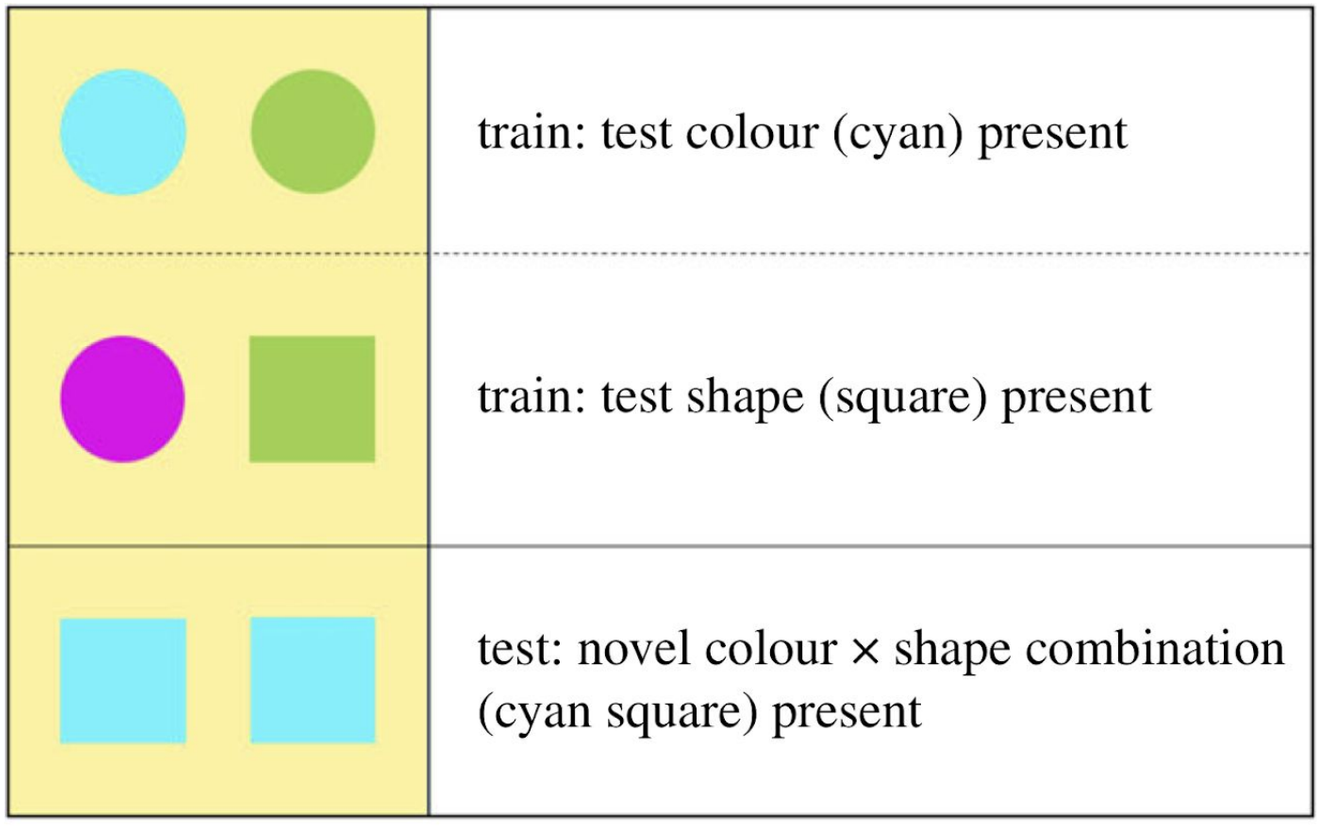


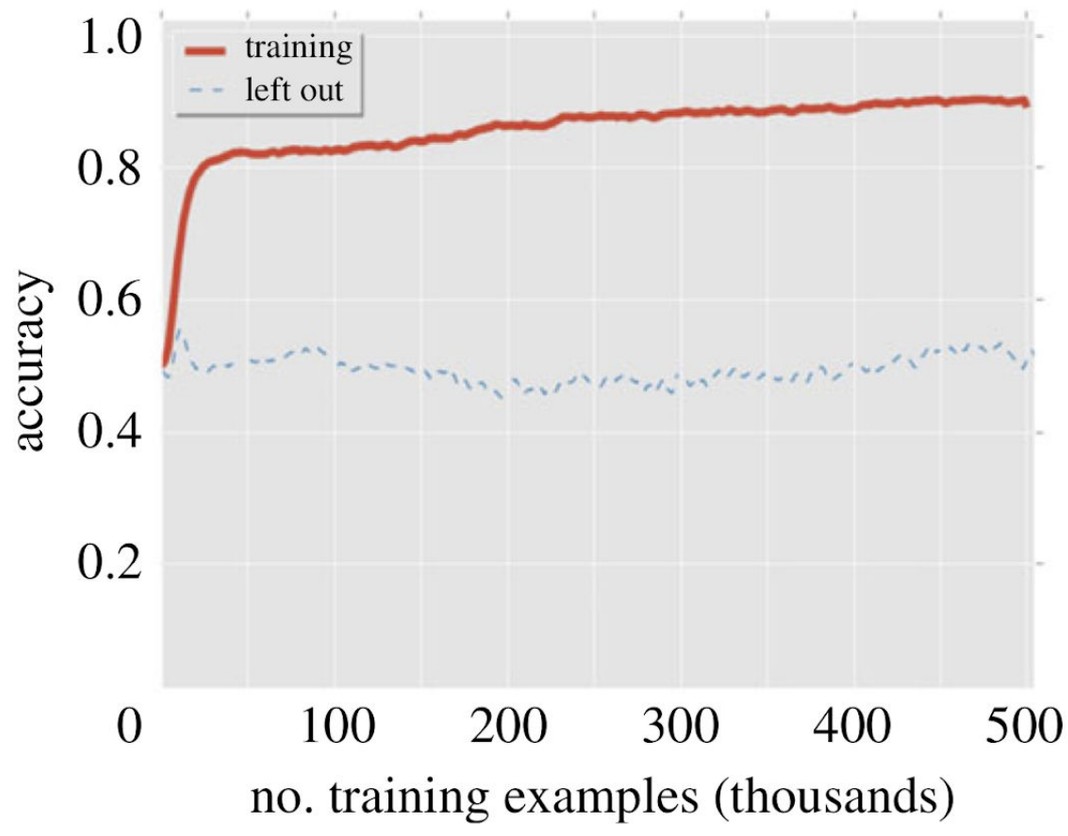


Martinho III & Kacelnik 2016

Visual reasoning

“Relational network”
(Santoro et al 2017)





Kim Ricci & Serre Royal Soc Interface Focus 2018

- Looking for potential collaborators for my wife (URI, nutrition, child obesity prevention)
- Contacts at the University?