Deep Topographic Models

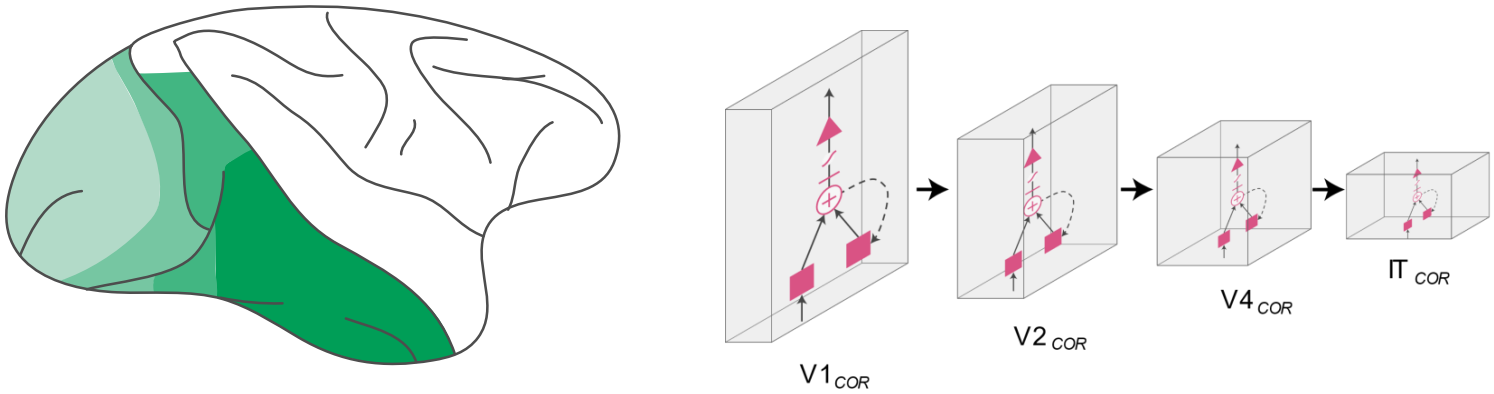
Predict the Behavioral Effects of Neural Perturbations in Primate Visual Cortex

Martin Schrimpf, Paul Mc Grath, James DiCarlo

C-BRIC Annual Review
October 5-7, 2021
Poster No. 18

Center for Brain Inspired Computing

Modeling primate vision



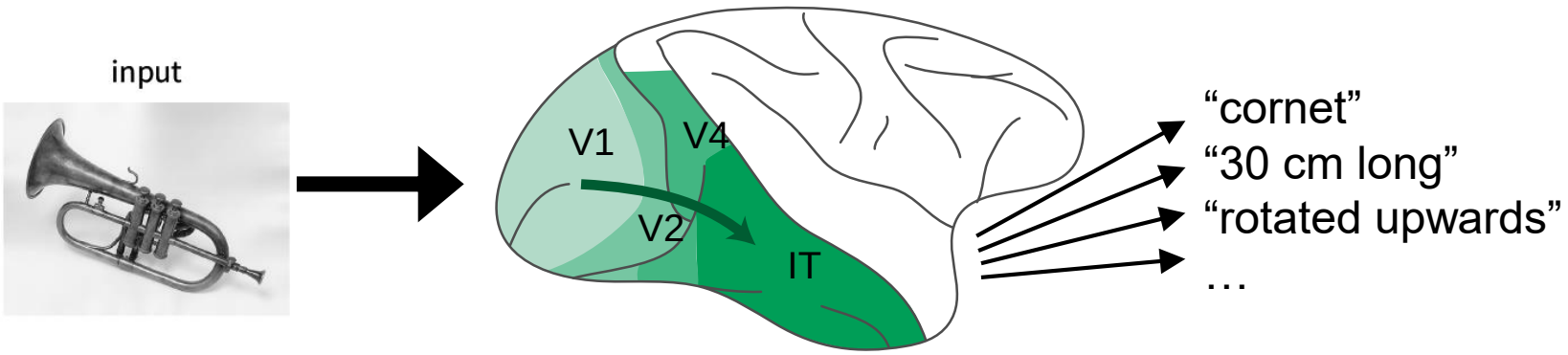
Mechanistic understanding of human object recognition

Next-generation visual intelligence algorithms

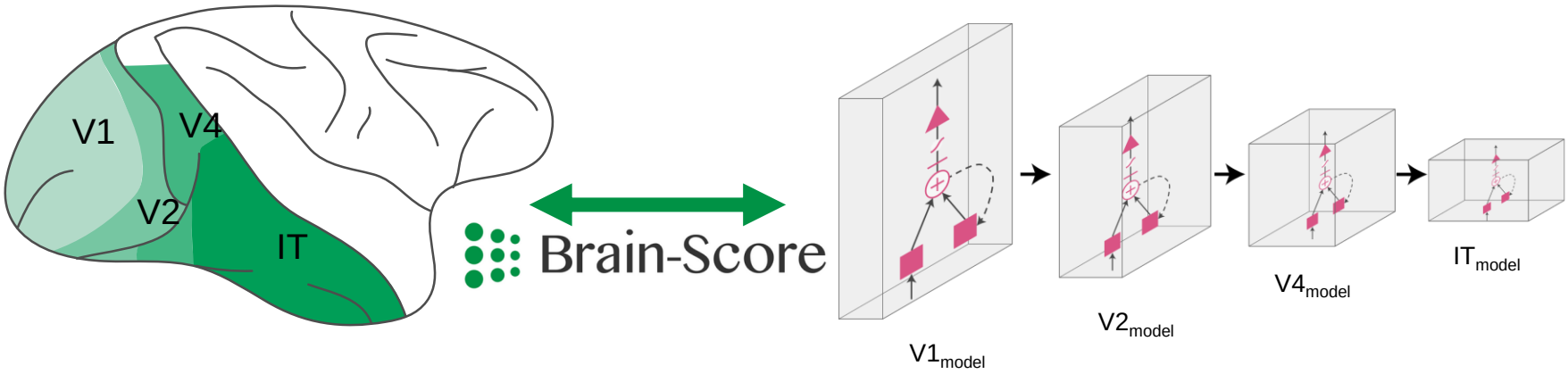
Future clinical applications

C-BRIC

Object recognition in the brain

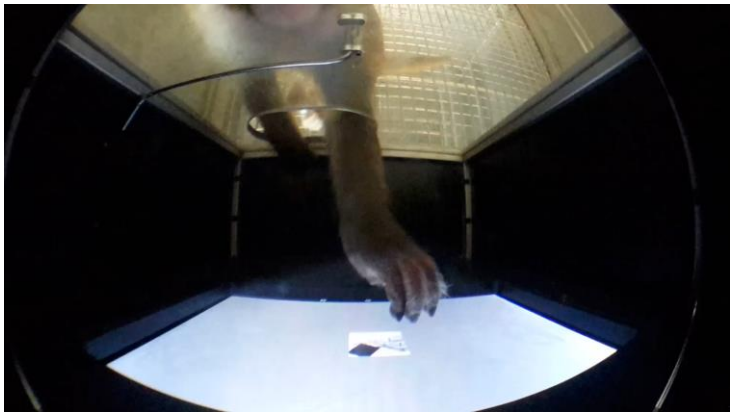


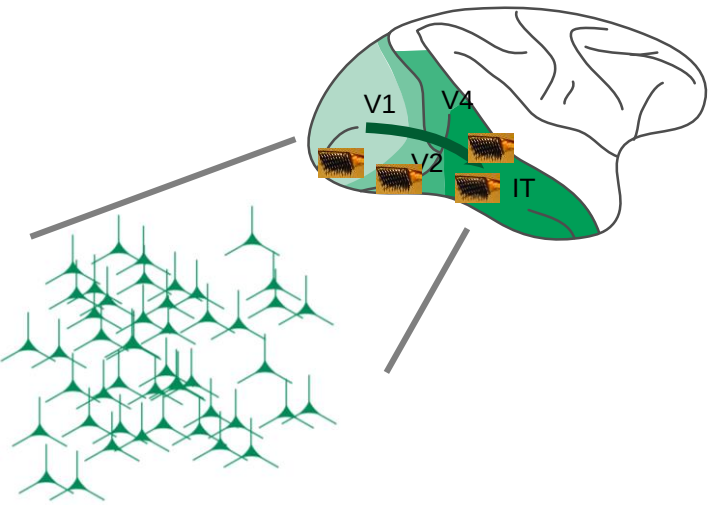
Modeling the ventral visual stream



Testing models of primate vision

Brain-Score.org tests model's match-to-brain with a range of neural and behavioral data under visual tasks

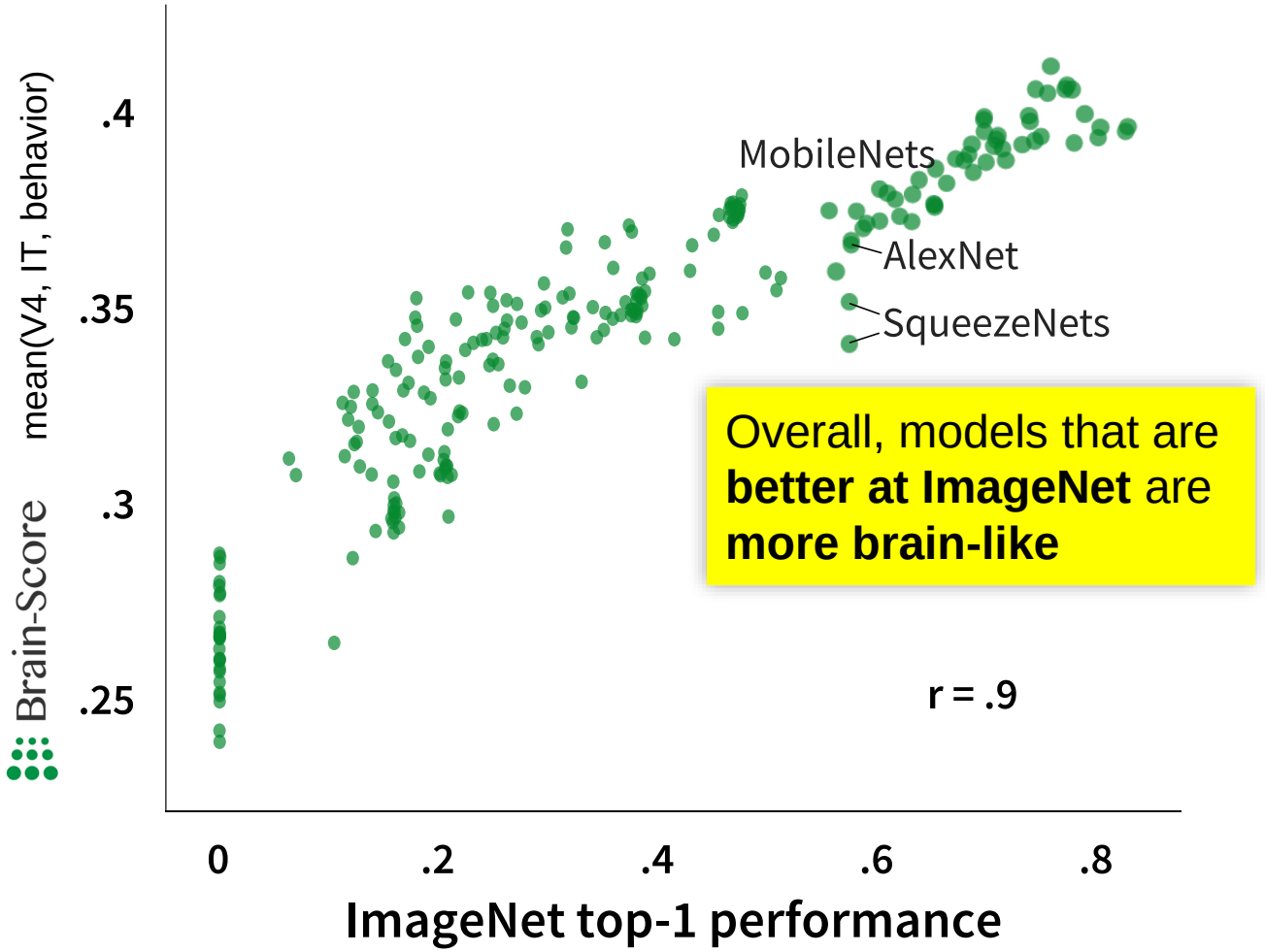




Brain-Score.org Leaderboard About Compare Participate

Rank	Model *submitted by*	average	V1 1 benchmark	V2 1 benchmark	V4 1 benchmark	IT 2 benchmarks	behavior 1 benchmark	engineering 1 benchmark
1	voneresnet-50-robust *Tiago Marques*	.431	.376	.391	.570	.274	.545	
2	VOneCORnet-S *Tiago Marques*	.427	.374	.261	.580	.424	.497	
3	voneresnet-50-non_stochastic *Tiago Marques*	.420	.387	.326	.584	.272	.530	.702
4	voneresnet-50 *Tiago Marques*	.419	.375	.334	.582	.270	.532	
5	CORnet-S *Martin Schrimpf*	.412	.294	.218	.581	.423	.545	
6	vgg-19 *Brain-Score Team*	.408	.347	.341	.610	.248	.494	.711
7	resnet-50-robust *Joel Dapello*	.408	.378	.365	.537	.243	.515	
8	resnet-101_v1 *Brain-Score Team*	.407	.266	.341	.590	.274	.561	.764
9	vgg-16 *Brain-Score Team*	.406	.355	.336	.620	.259	.461	.715
10	resnet-152_v1 *Brain-Score Team*	.405	.282	.338	.598	.277	.533	.768
11	resnet-101_v2 *Brain-Score Team*	.404	.274	.332	.599	.263	.555	.774
12	resnet50-SIN_IN	.404	.282	.324	.599	.276	.541	.746

Particular high-performing ANNs are decent models of primate vision

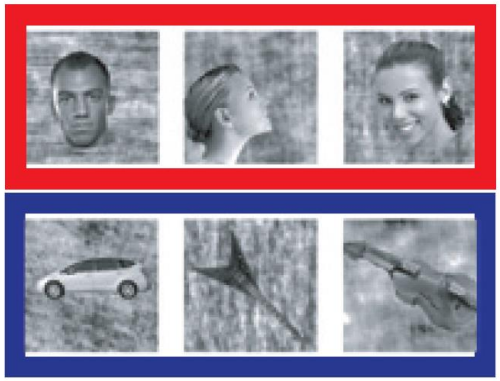


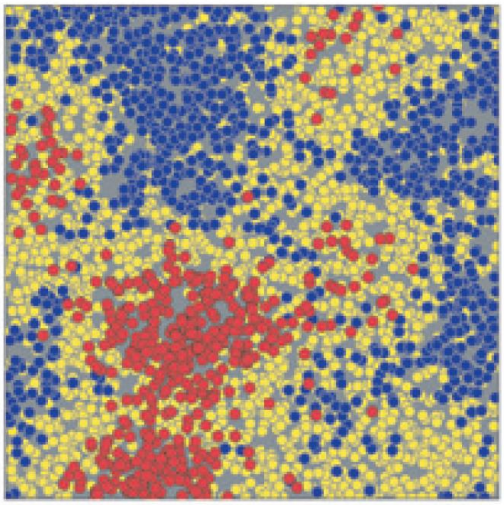
Schrimpf & Kubilius et al. 2018; Kubilius & Schrimpf et al. 2019; Schrimpf et al. 2020

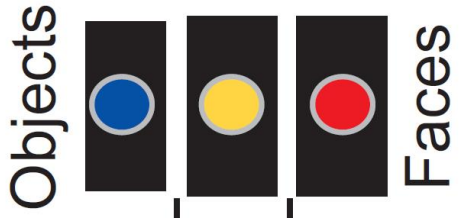
C-BRIC

But key properties of primate visual processing are still missing

- Visual cortex is organized topographically – **neurons that are similar** tend to **cluster together**
- This leads to the emergence of so-called face patches: spatial clusters of neurons that preferentially respond to faces
- Such topography might be the result of **efficient wiring-cost optimization**
- We tested the necessity of neuronal spatial organization to **predict the behavioral effects of perturbations**



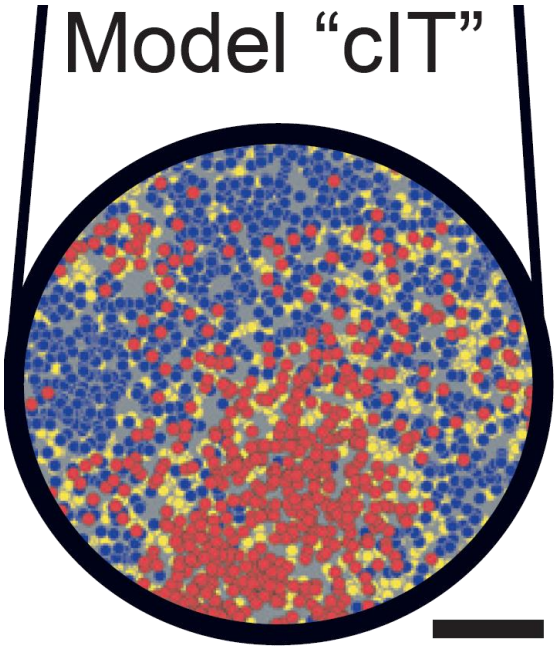


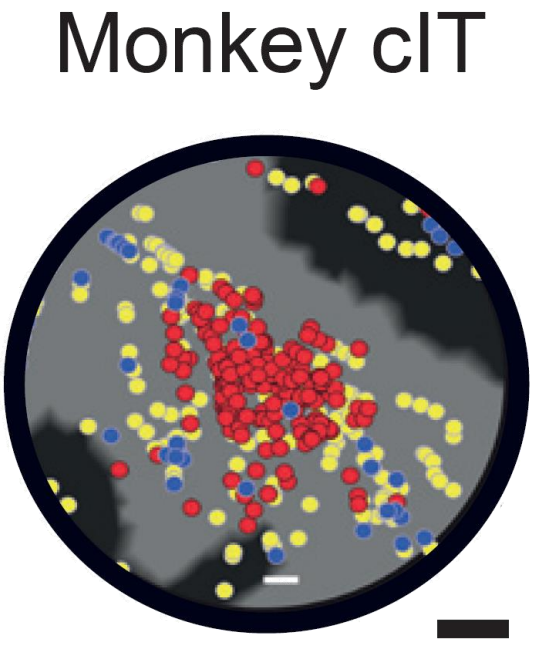


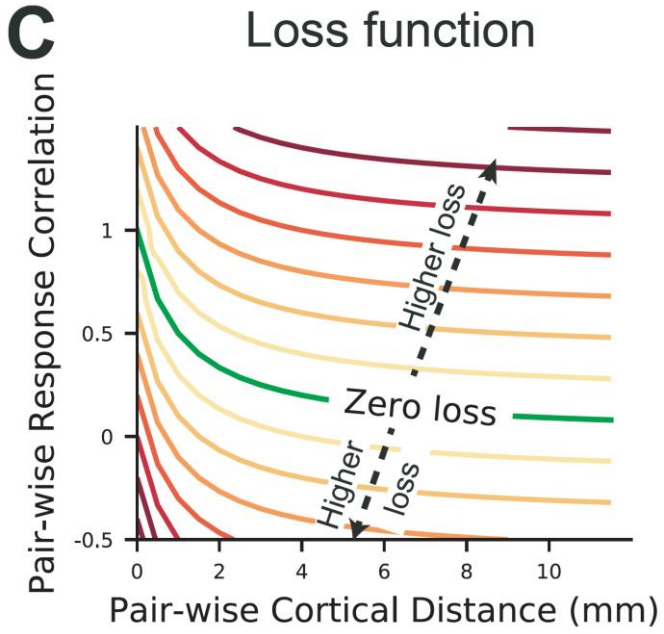
Lee et al. 2020

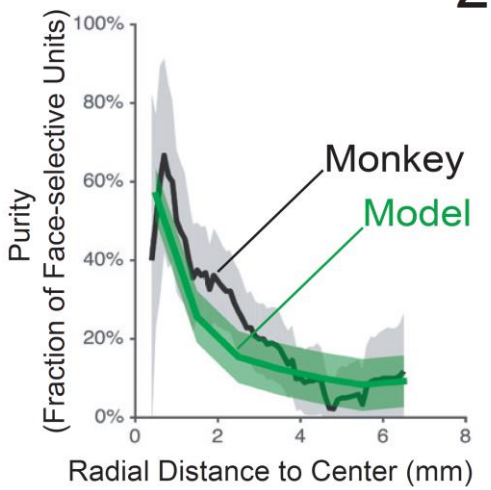
Topographic models replicate the spatial layout of neurons in primate cortex

- Train models with spatial correlation loss
- → ~match to primate topography









Lee et al. 2020

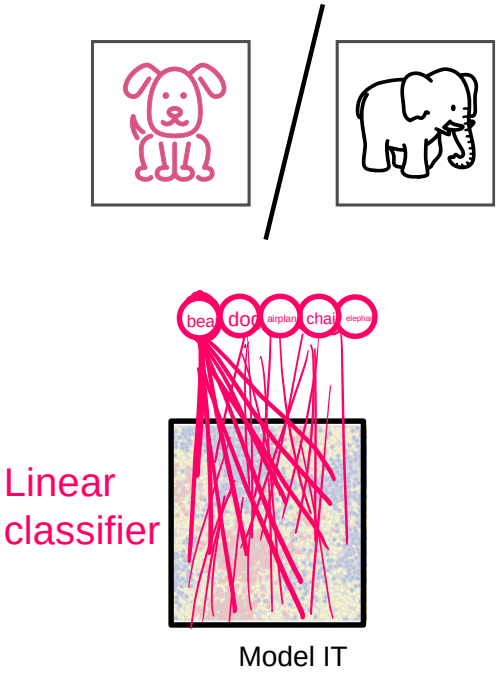
C-BRIC

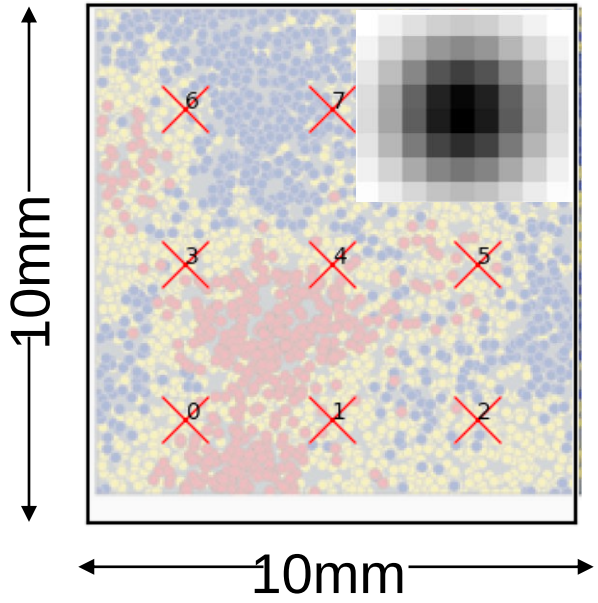
Running perturbation experiments on topographic model

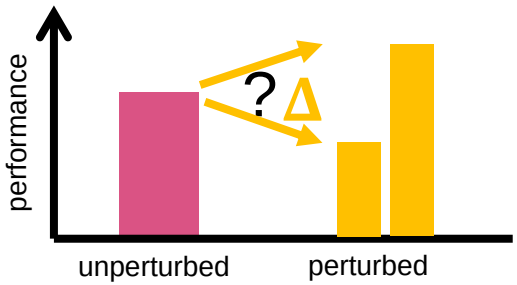
1. Train classifier on categorization task with un-perturbed features

2. Inject at specified sites in model tissue

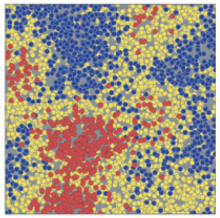
3. Measure behavioral effects, compare with data

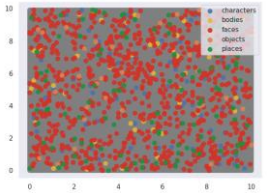






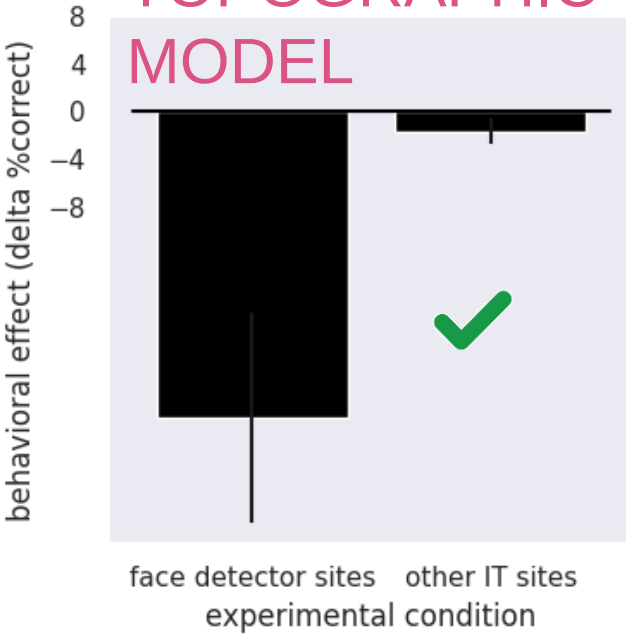
The topographic model reproduces experimental data to a first extent



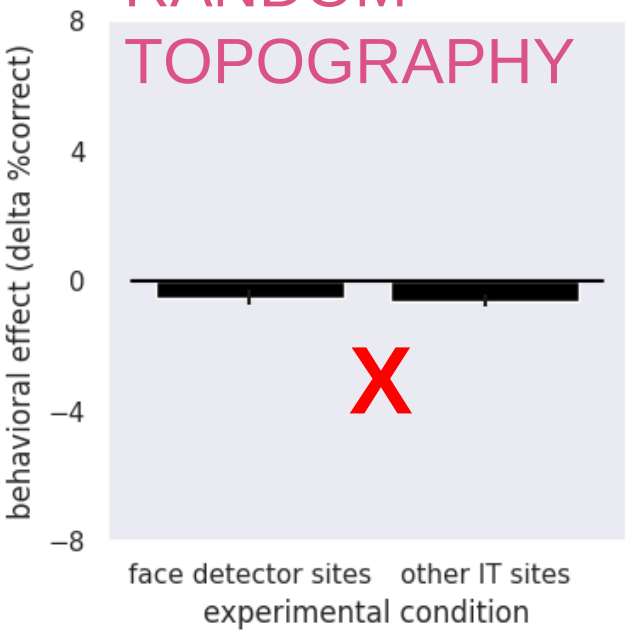


DATA (Afraz et al. 2015)

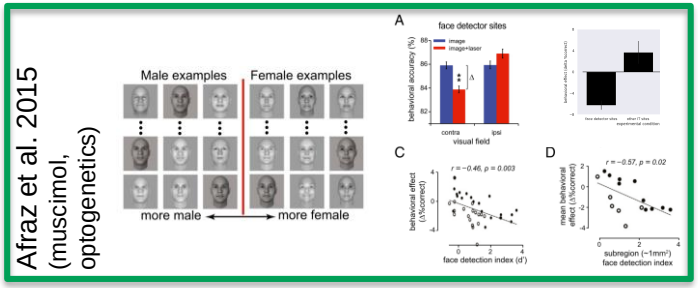
TOPOGRAPHIC MODEL

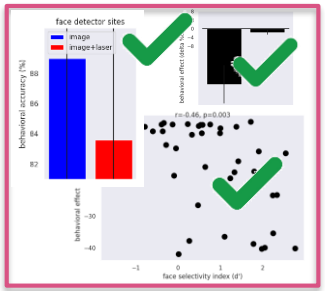


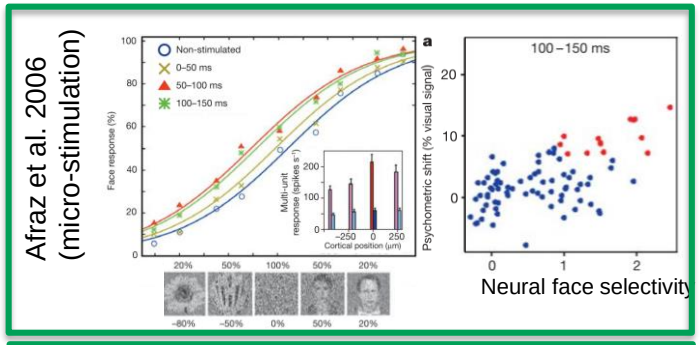
RANDOM TOPOGRAPHY

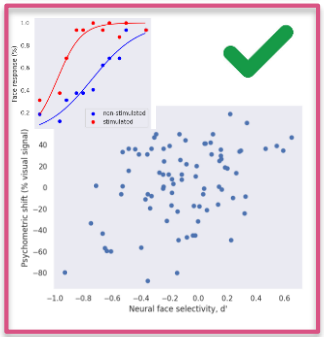


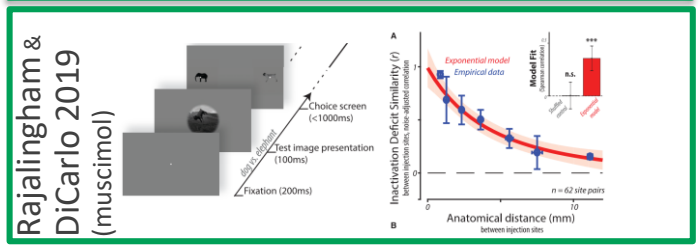
The topographic model qualitatively reproduces a range of experimental data

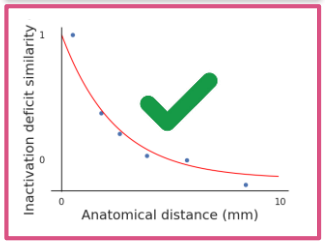




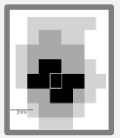
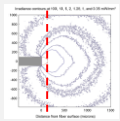
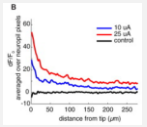








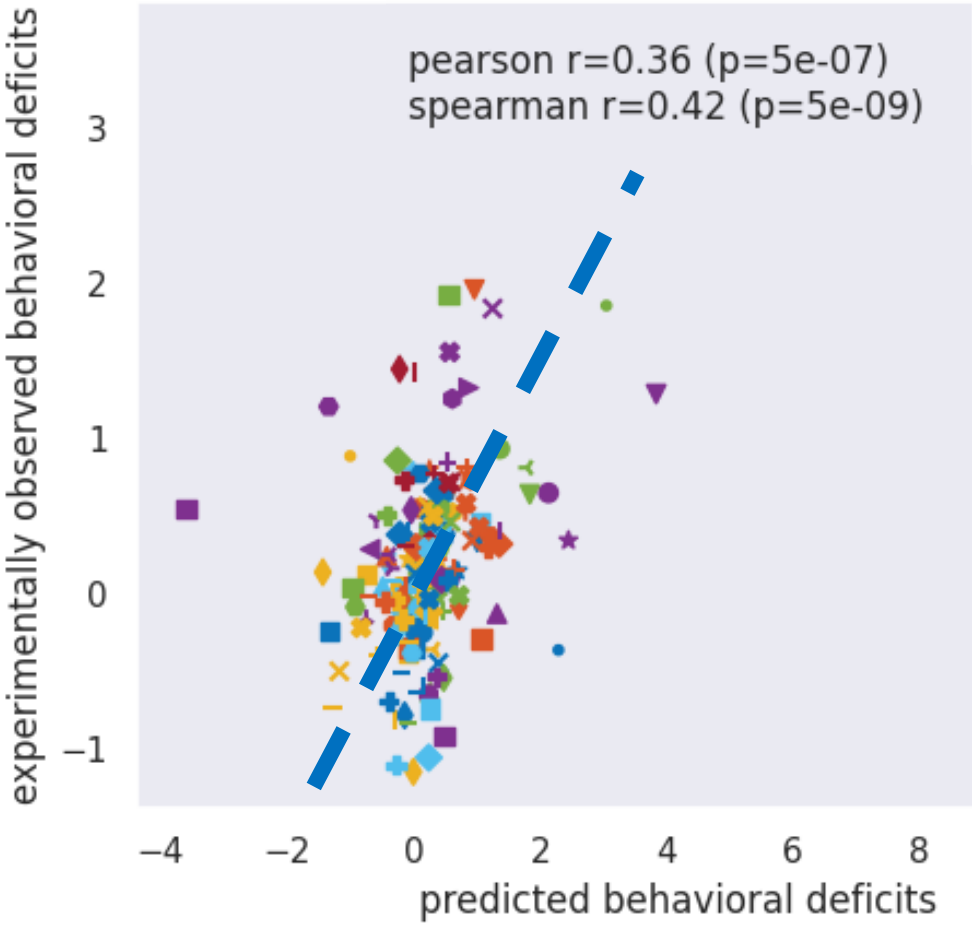
Perturbation parameters locked down

muscimol	Arikan et al. 2002	
opto	Chow et al. 2010 Bernstein*, Han* et al. 2008	
microstim	Histed et al. 2009	

C-BRIC

Potential steps towards BMI: the topographic model predicts precise perceptual effects

- The model can tell us what **perceptual change** a given perturbation will elicit
- In the future, we are planning to use this model for **guided stimulation experiments** to elicit visual percepts
- With C-BRIC colleagues, there might be synergies in **efficient wiring** layouts



C-BRIC