

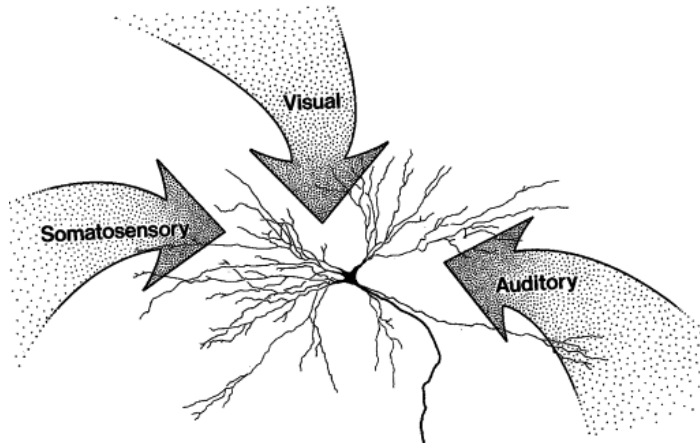
Principles of domain-general cognition

in neuroscience and artificial intelligence



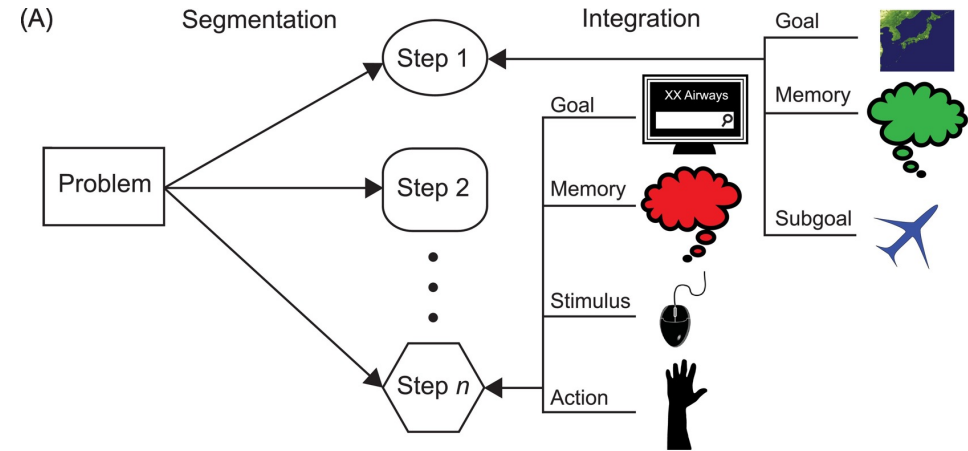
Domain-general cognition in brains & AI

Domain-general information



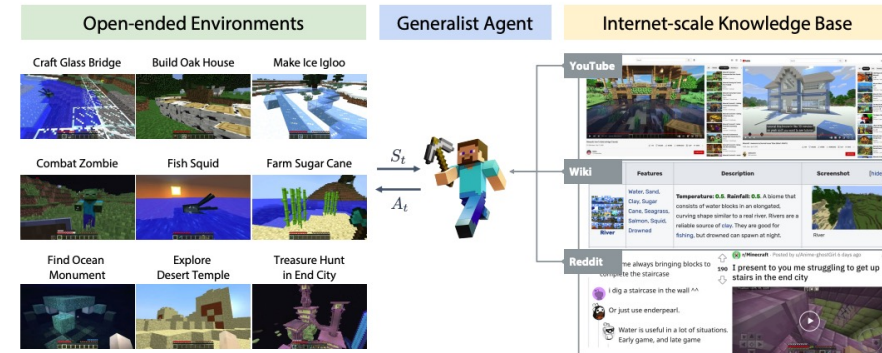
(From Stein et al., 2002, Encyclopedia of the Human Brain, 'Multisensory Integration')

Abstract compositional problem solving



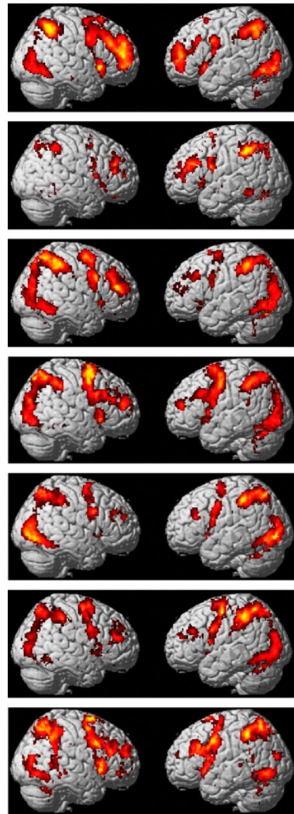
(Duncan et al., 2020, TICS)

New challenges in AI: Open-ended & flexible cognition

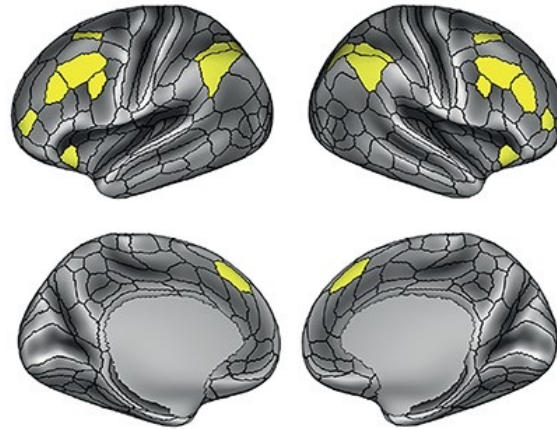


(Fan et al., 2022, NeurIPS)

The Multiple Demand (MD) system

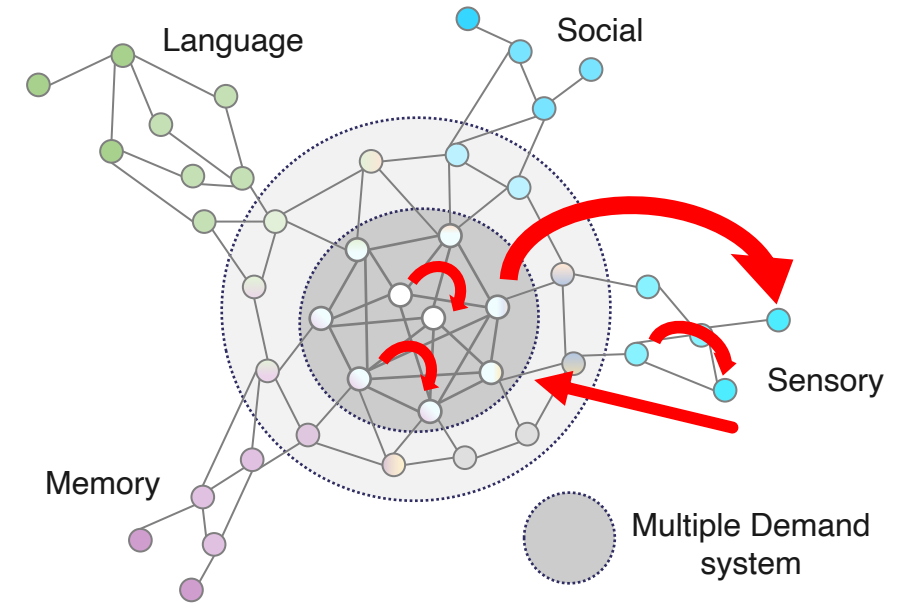


A network for domain-general problem solving...



(Duncan et al., 2020, TICS; Assem et al., 2020 Cerebral Cortex; Fedorenko et al. 2013, PNAS)

...forming a central processing unit...

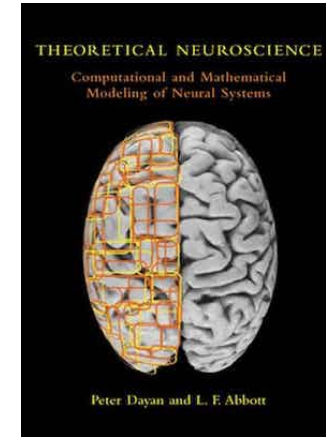


...with unique recurrence, network communicability and topological dynamics.

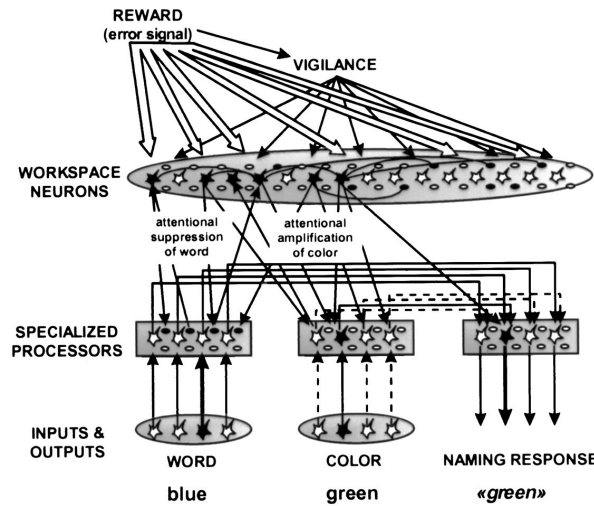
(Achterberg et al., 2023, AAAI EDGeS / ArXiv; Mashour et al. 2020, Neuron)

Studying cognition with computational models

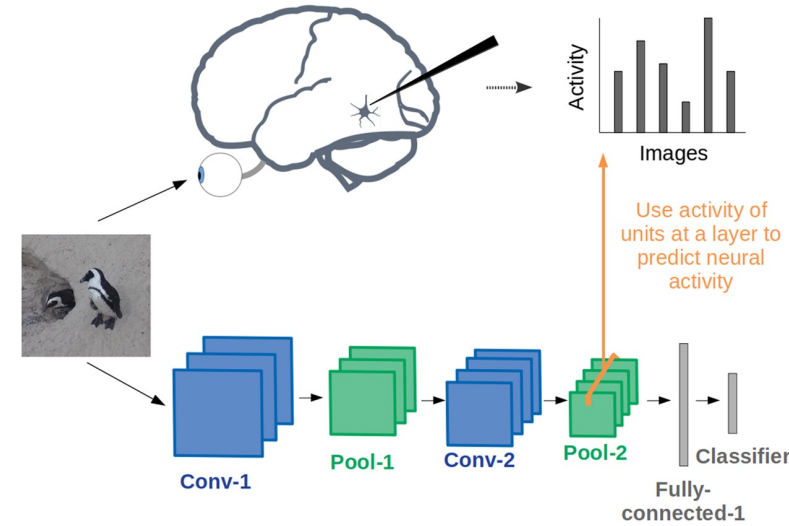
- Synergistic study of computational models (AI) and neuroscience to understand fundamental processes of cognition (e.g. see Zador et al. 2023, Nat Comms)



(Dayan & Abbott, 2001: "Theoretical Neuroscience")



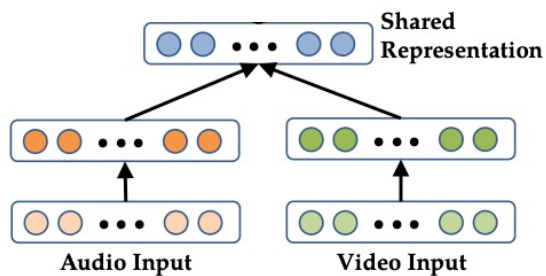
(Dahaene et al., 1998, PNAS)



(Lindsay, 2021, JoCN)

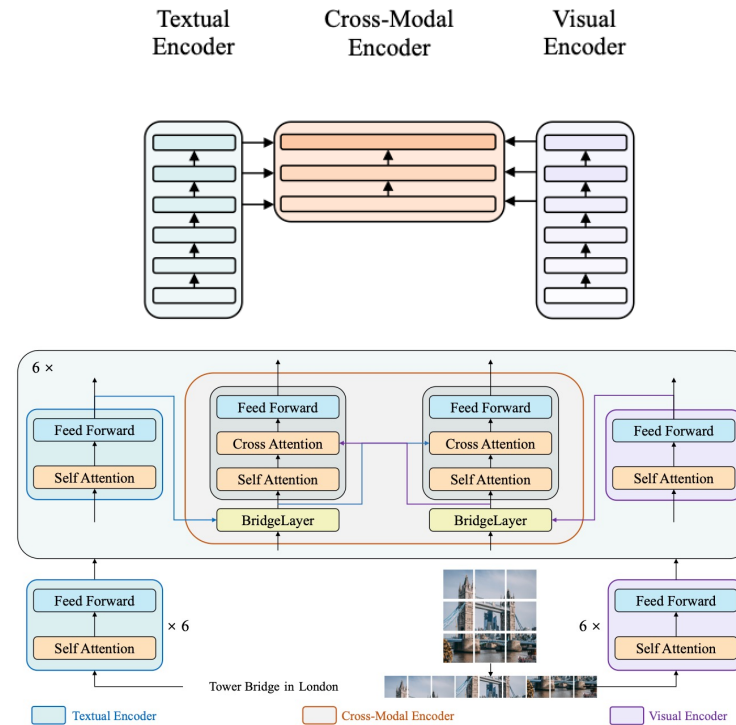
Towards domain-general cognition in AI

Towards multimodal AI



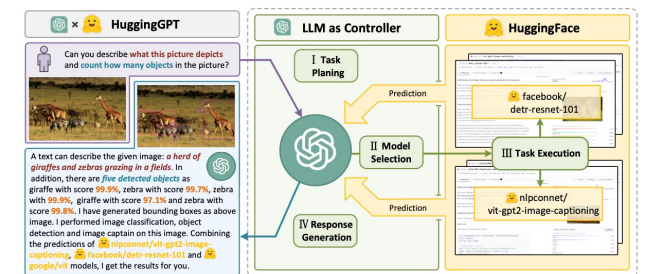
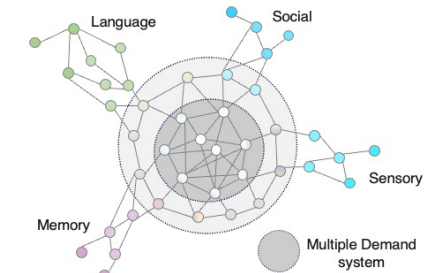
(Ngiam et al., 2011, ICML)

BridgeTower Multimodal systems-level architecture



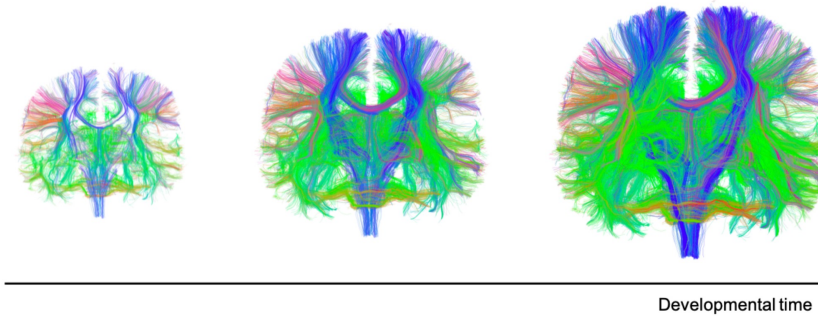
(Xu et al., 2022, AAI)

Transfer to neuroscience:
Can we move from basic tasks in simple architectures to testing systems-level function in models?

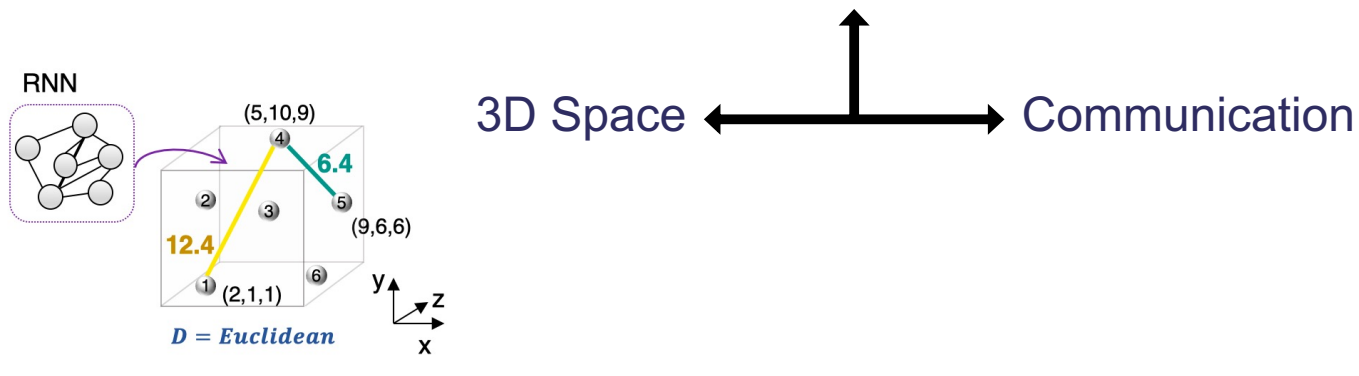


(Achterberg et al., 2023, AAI EDGeS / ArXiv; Shen et al., 2023, ArXiv)

Systems-level embedding of neural networks: *The spatially-embedded RNN* (Achterberg et al., 2022, bioRxiv)



While the brain is acquiring its functions,
it is structurally impacted by:



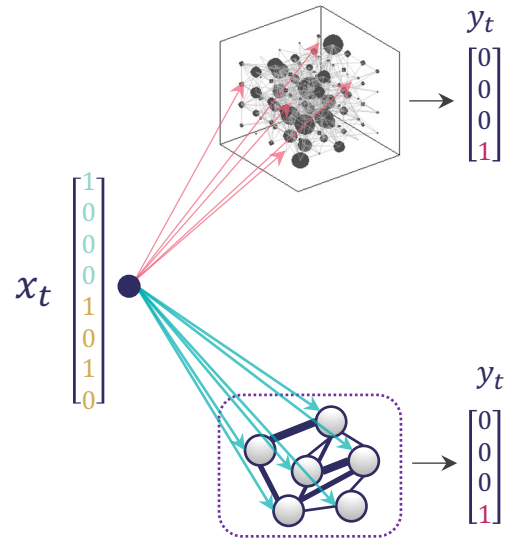
Systems-level embedding of neural networks: *The spatially-embedded RNN* (Achterberg et al., 2022, bioRxiv)

Spatially-embedded RNN

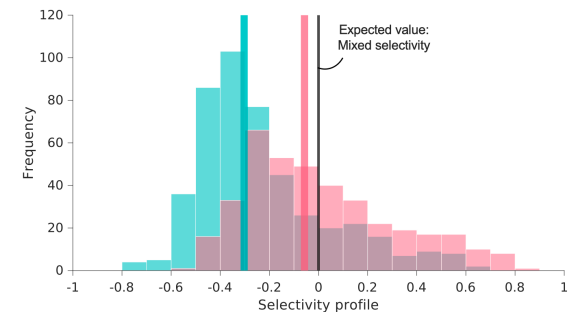
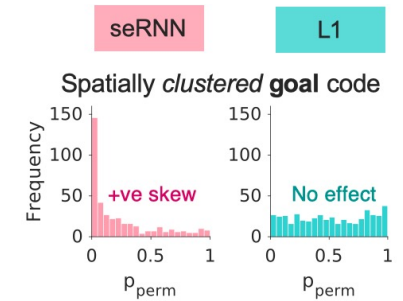
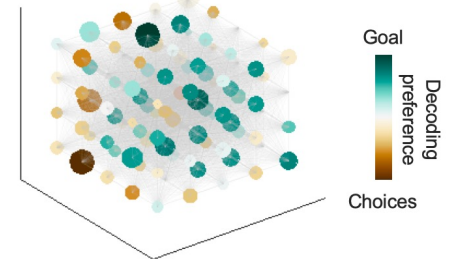
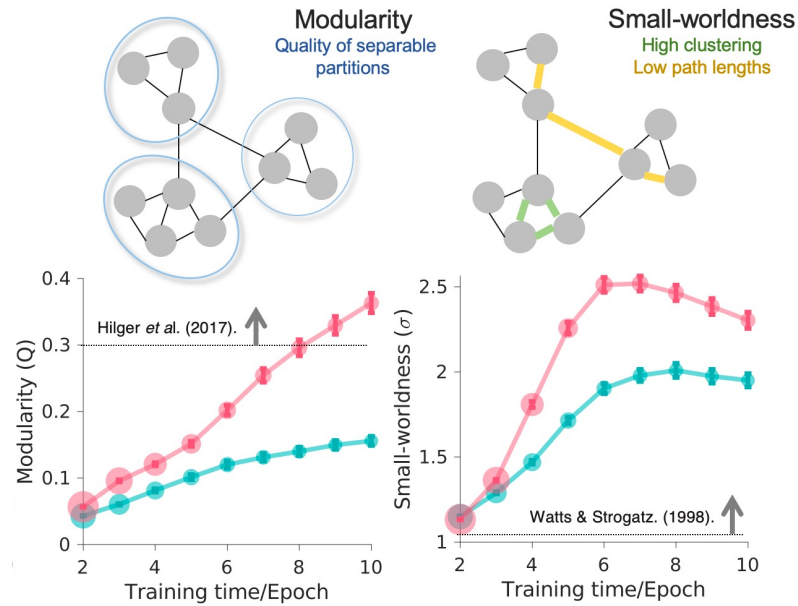
Embedded networks show brain-like structure...

...and function

Task-relevant inputs



Baseline model



The 21st century will give us the
unique opportunity to understand
fundamental principles of
cognition...

...by studying them in brains and
artificial systems!

<https://www.jachterberg.com/neuroai>



Jascha Achterberg
jachterberg.com
ja651@cam.ac.uk
@achterbrain

BUILDING ARTIFICIAL NEURAL CIRCUITS FOR
DOMAIN-GENERAL COGNITION:
A PRIMER ON BRAIN-INSPIRED SYSTEMS-LEVEL
ARCHITECTURE *

Jascha Achterberg
University of Cambridge & Intel Labs
jascha.achterberg@mrc-cbu.cam.ac.uk

Danyal Akarca
University of Cambridge
danyal.akarca@mrc-cbu.cam.ac.uk

Moataz Assem
University of Cambridge
moataz.assem@mrc-cbu.cam.ac.uk

Moritz Heimbach
Julius-Maximilians-Universität Würzburg
moritz.heimbach@uni-wuerzburg.de

Duncan E. Astle
University of Cambridge
duncan.astle@mrc-cbu.cam.ac.uk

John Duncan
University of Cambridge
john.duncan@mrc-cbu.cam.ac.uk

<https://arxiv.org/abs/2303.13651>