What's "neural" about neural networks?

On the similarities and differences between artificial and natural intelligence

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iBehave Open Technology Support (iBOTS)

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Agenda

- The (historical) relationship between neuroscience and AI
- Why AI researchers should care about neuroscience
- How to compare ANNs and brains
- Fundamental difference between ANNs and intelligent biological agents

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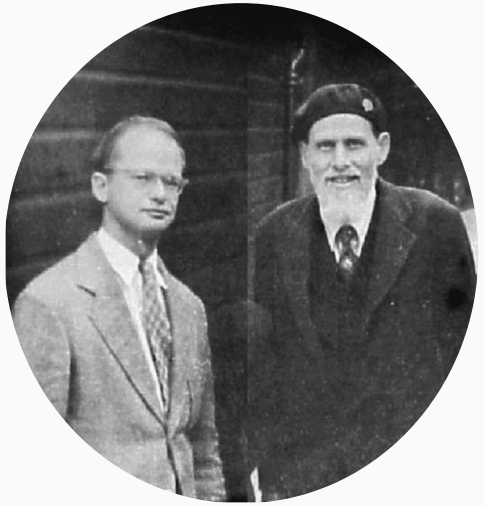
How it started ...



Neural computation: neurons can implement logical operations and networks of such neurons are capable of universal computation (McCulloch and Pitts 1943).

Hebbian learning: Randomly wired networks can learn through input driven reinforcement of synaptic connections (Hebb 1949)

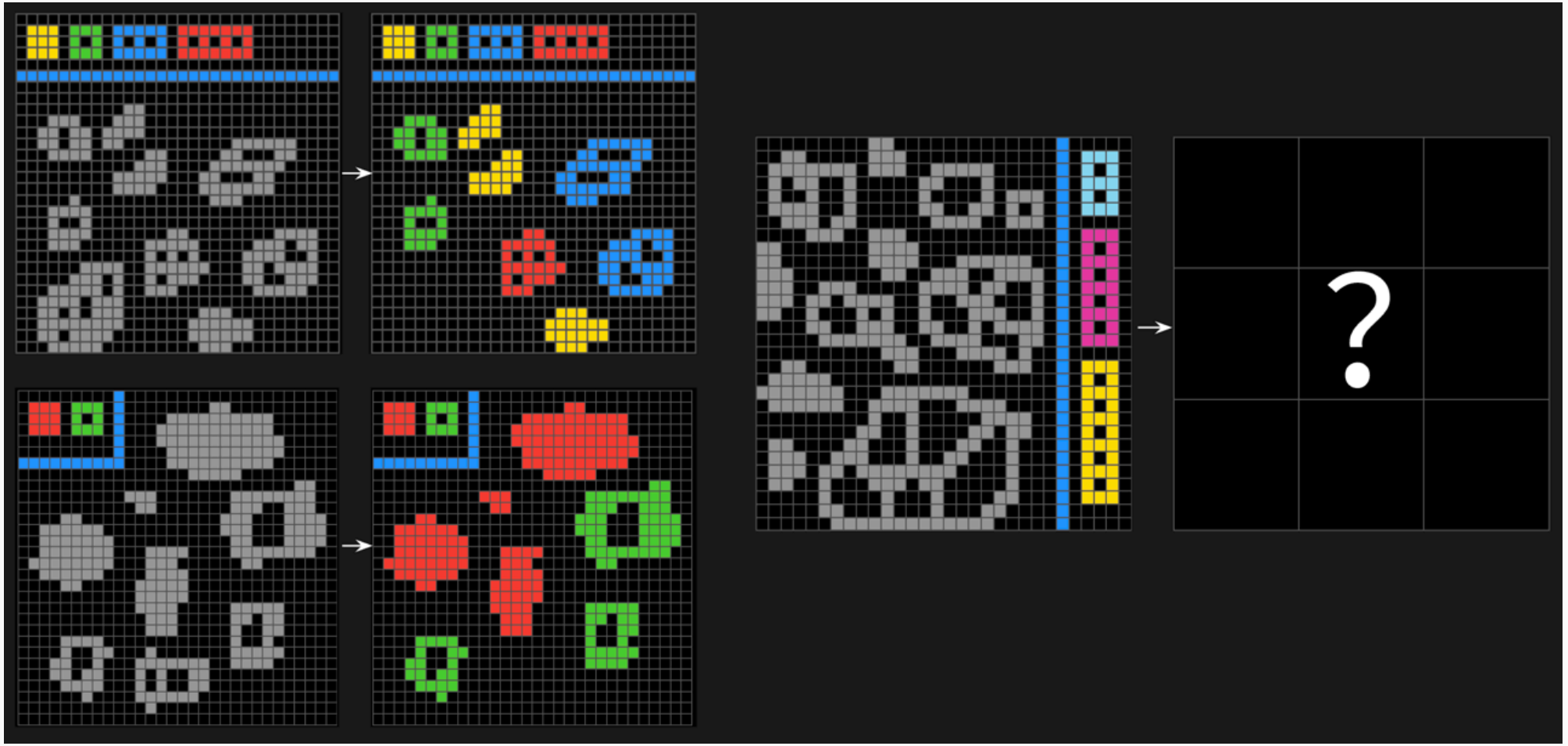
How it’s going…

You can’t brute force intelligence

What is Intelligence ?

- **Skill** is how is the ability to perform a given task (e.g. playing chess)
- **Intelligence** is the ability to acquire-new skills and generalize to new problems (Chollet 2019)
- The Abstraction and Reasoning Corpus (**ARC**) is a set of tests aiming to benchmark intelligence (ARC leaderboard)

Example of an ARC task

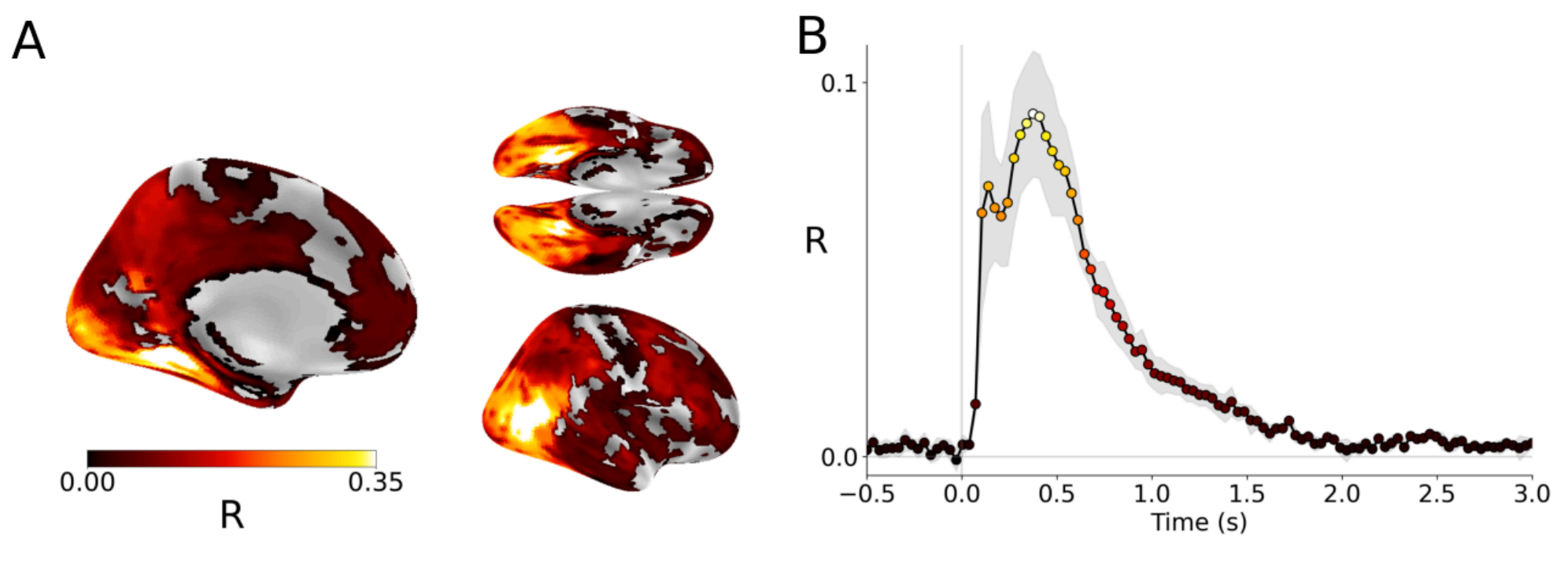


ARC-AGI-2 Public Eval Task #e3721c99

Comparing Brains and Neural Networks

Relating Model Activation to Brain Recordings

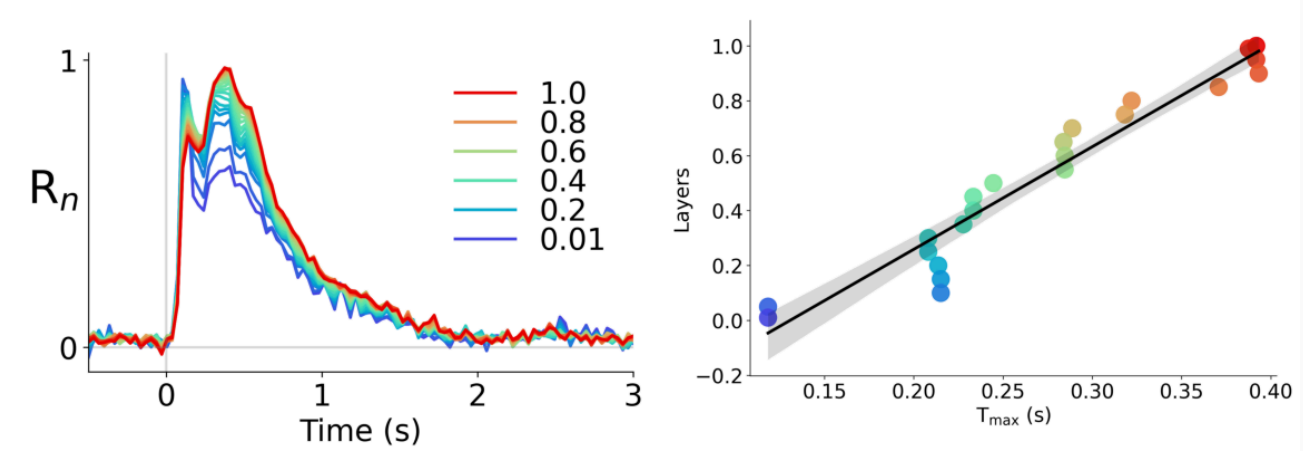
- Show the same stimuli (e.g images) to Humans and Models
- Find mapping W between brain activity Y and model activation X
- Correlate the prediction from model activation to the actual brain recording: $R^{(d)} = \text{corr}(WX_{test}, y_{test})$



Raugel et al. (2025): Disentangling factors of convergence between brains and computer vision models

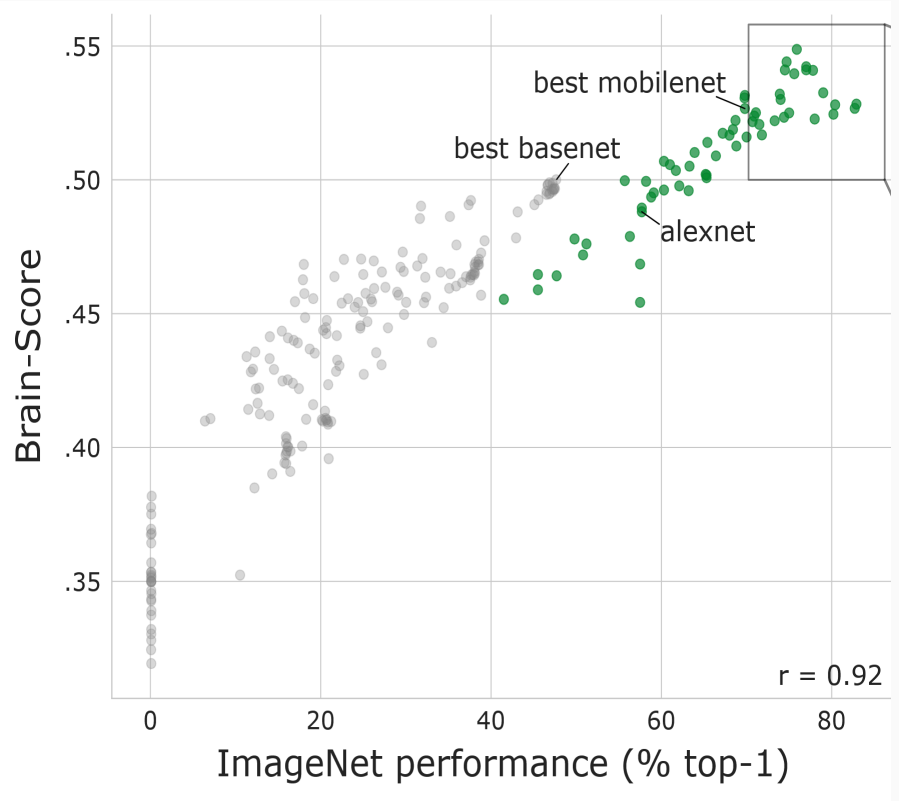
Corresponding Representational Hierarchies

- Early and late layers align with the earliest and latest brain responses



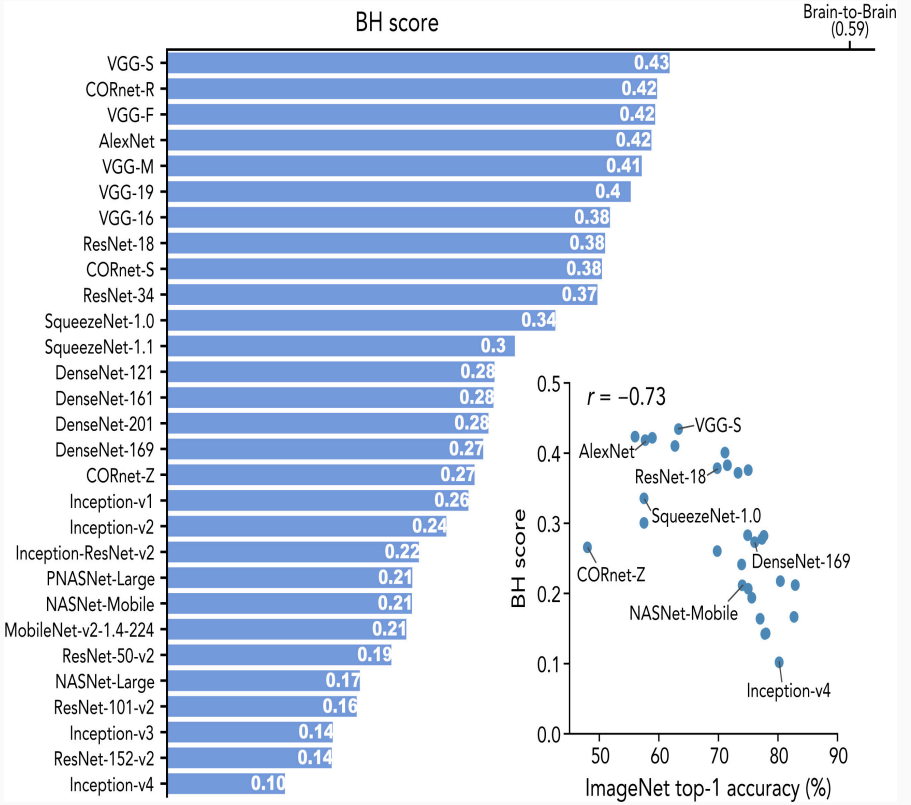
Different Architecture, Convergent Solutions

- Better ImageNets are more predictive of brain activity



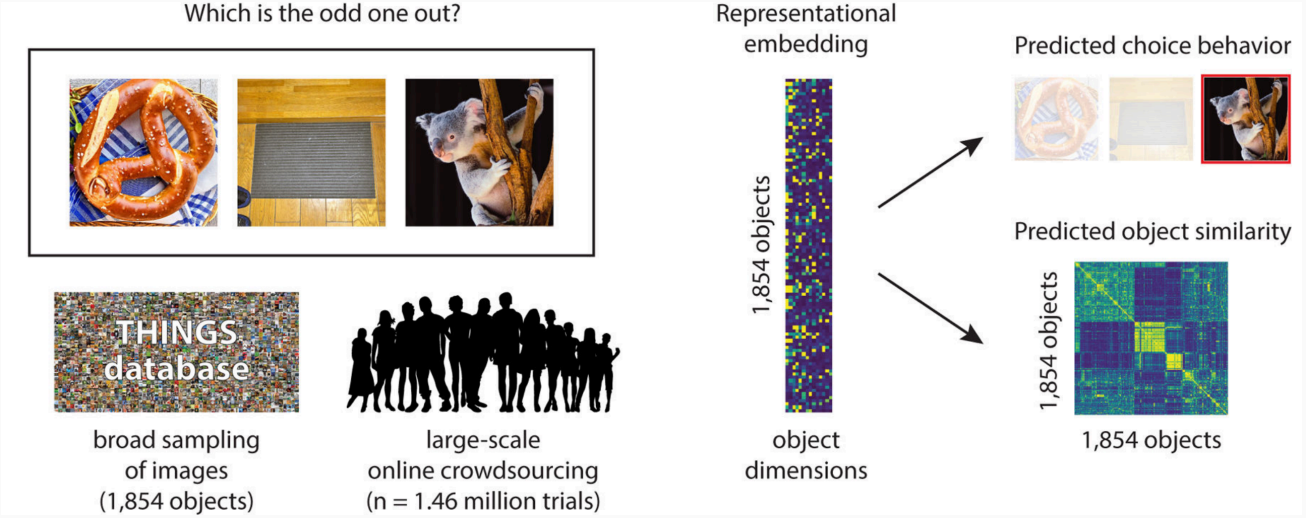
Schrimpf et al. (2018): Brain-score: Which artificial neural network for object recognition is most brain-like?

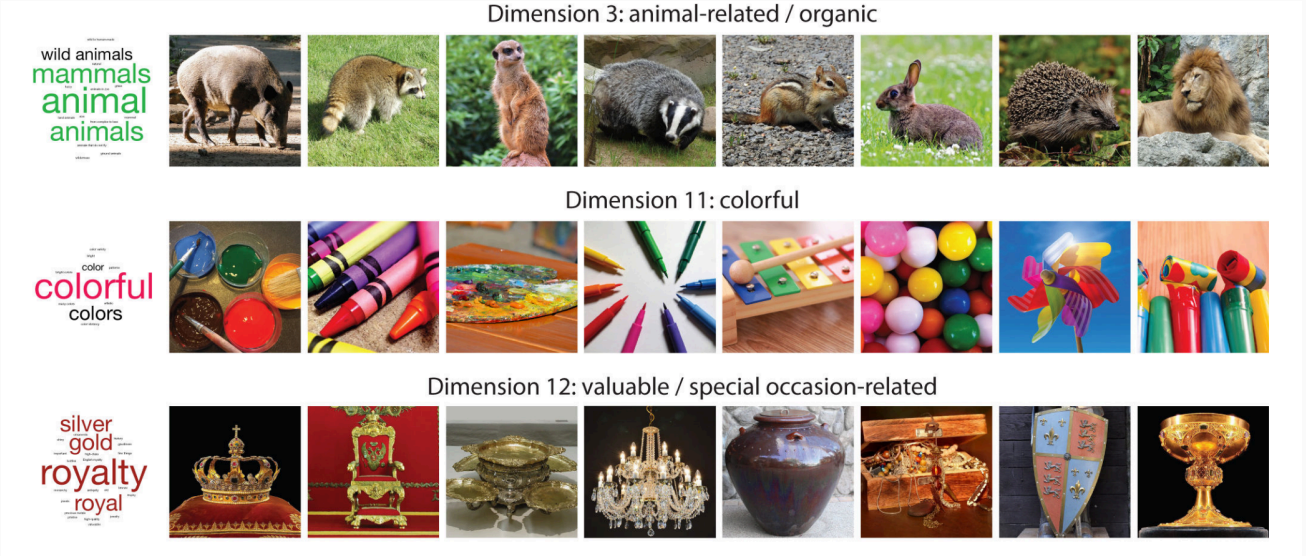
- Not every model maps onto the neural hierarchy



Nonaka et al. (2021): Brain hierarchy score: Which deep neural networks are hierarchically brain-like?

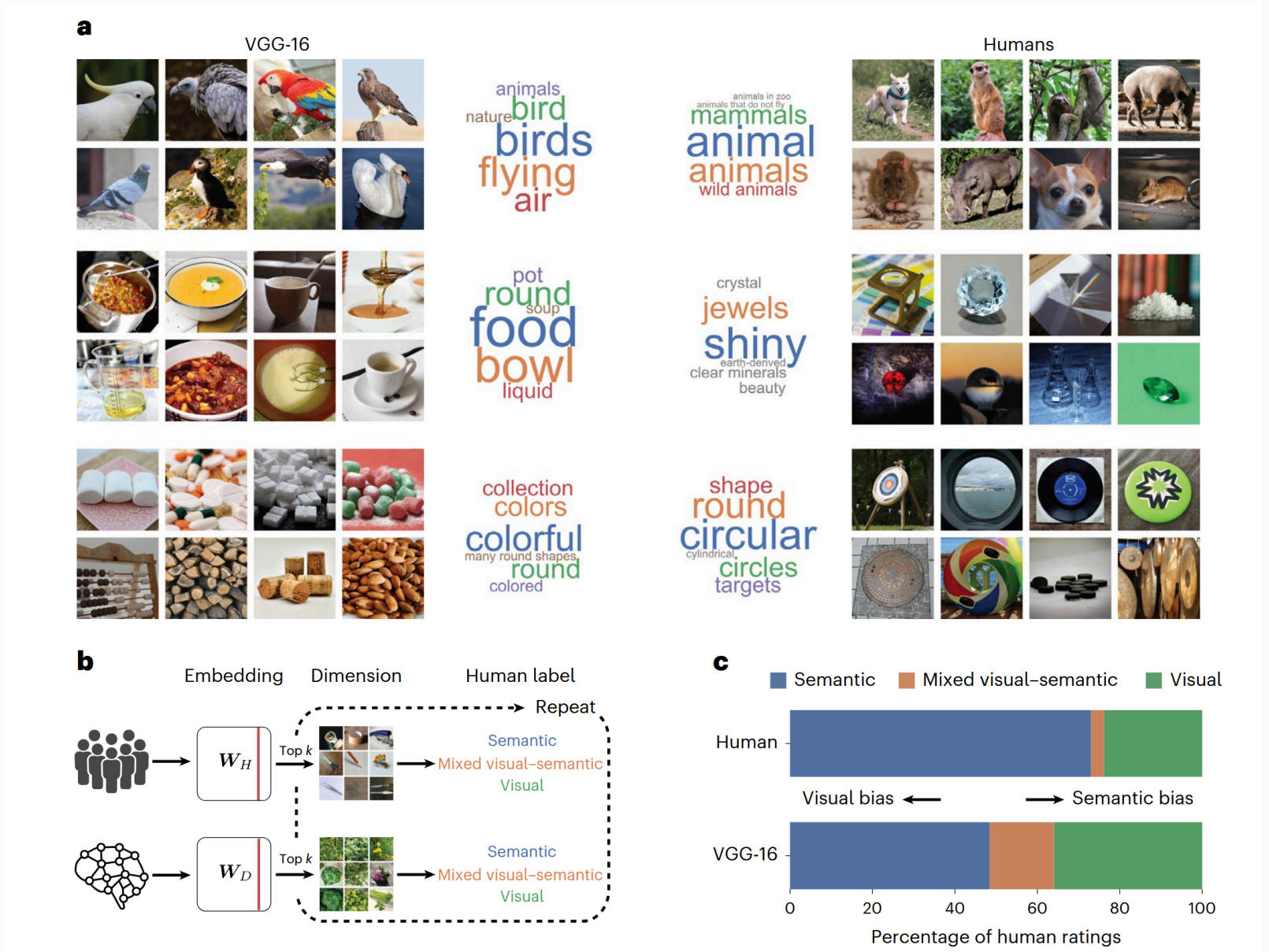
Comparing Humand and Model Behavior





Hebart et al. (2020): Revealing the multidimensional mental representations of natural objects underlying human similarity judgements

Different Dimensions of Interest

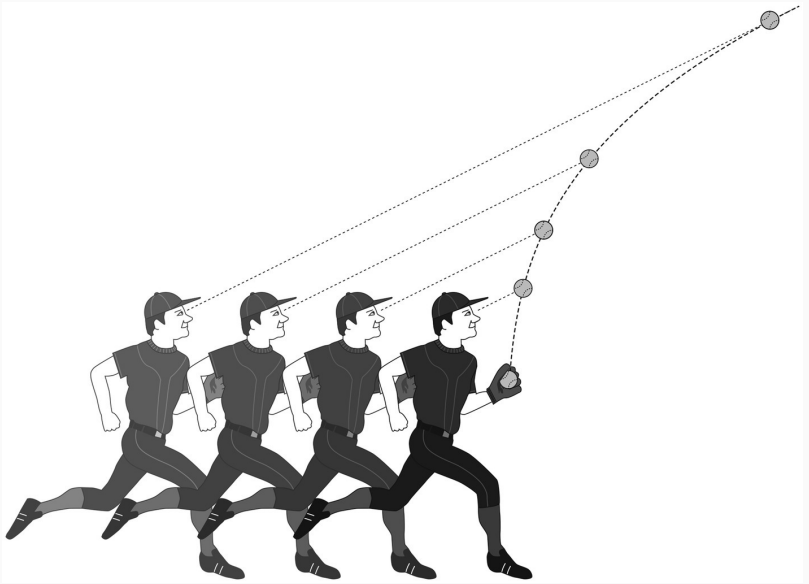


Mahner et al. (2025): Dimensions underlying the representational alignment of deep neural networks with humans

Fundamental Differences between Artifical and Biological Intelligence

Emodied Cognition

- AI is purely computational/statistical inference but human cognition is physically embodied
- Human cognition can extend beyond the brain into the body and environment
- Example: the gaze heuristic



Gigerenzer (2021): Embodied Heuristics

- Because human cognition is embodied, **complicated inference** problems can be solved by **simple heuristics**

Are AI “Agents” Real Agents?

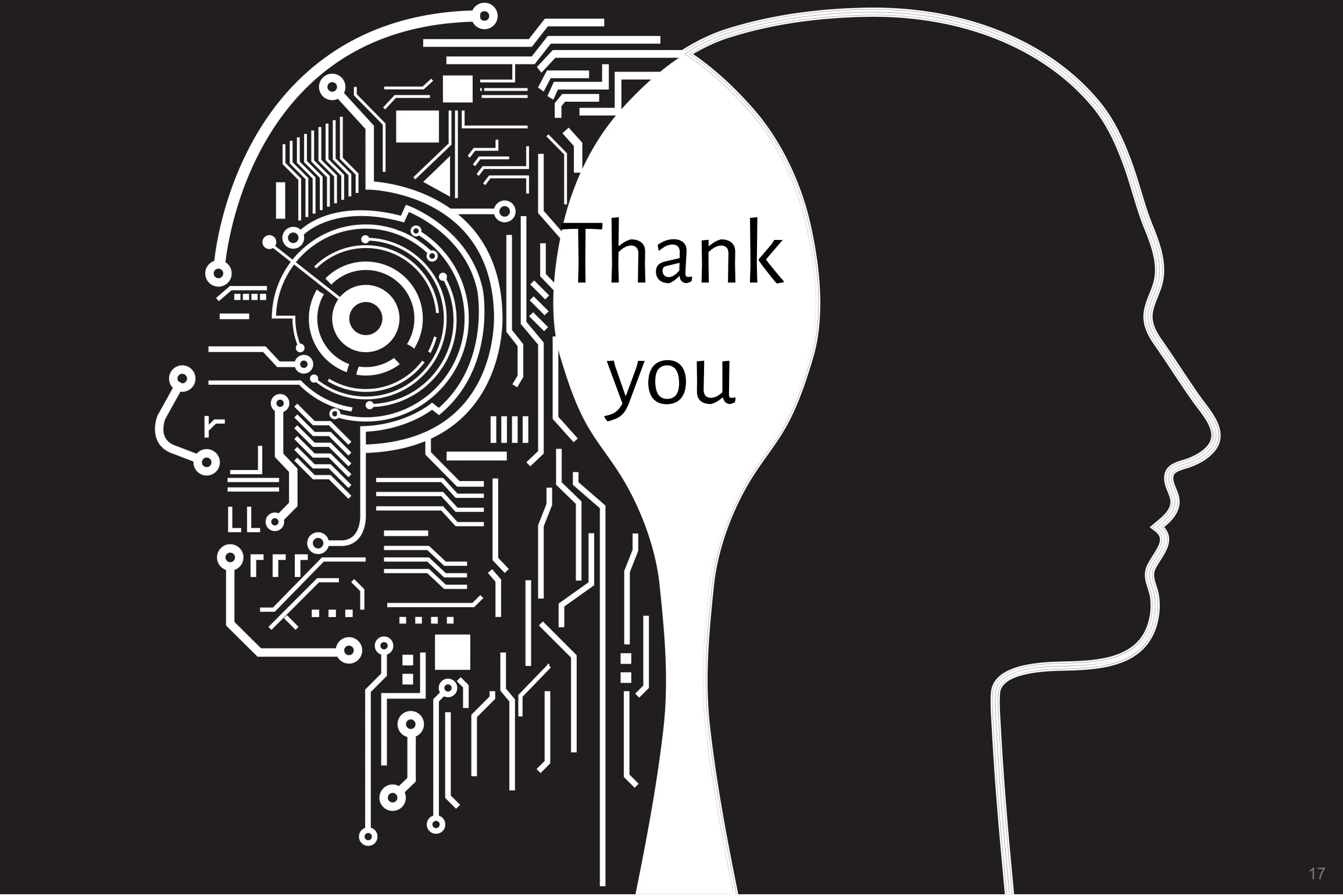
Biological Agents

- Are **autopoietic** (i.e. self-manufacturing)
- Are **internally motivated** to self-preserve and act autonomously
- Live in a large world of **ill-defined** problems and have to decide what is relevant

Artificial Agents

- Are programmed by an **external agent**
- Are **externally motivated** and triggered by an external agent
- Live in a small world of **well-defined** problems and operate within **predefined** formalized ontology

See Jaeger et al. (2024): Naturalizing relevance realization: why agency and cognition are fundamentally not computational


Thank
you

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