Brain-derived signals for Human-centric AI

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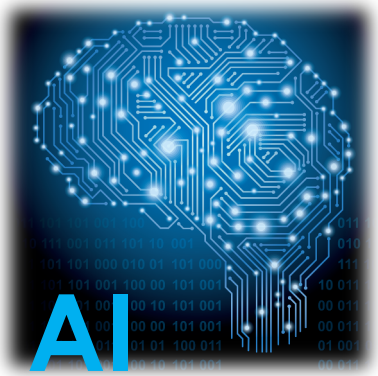
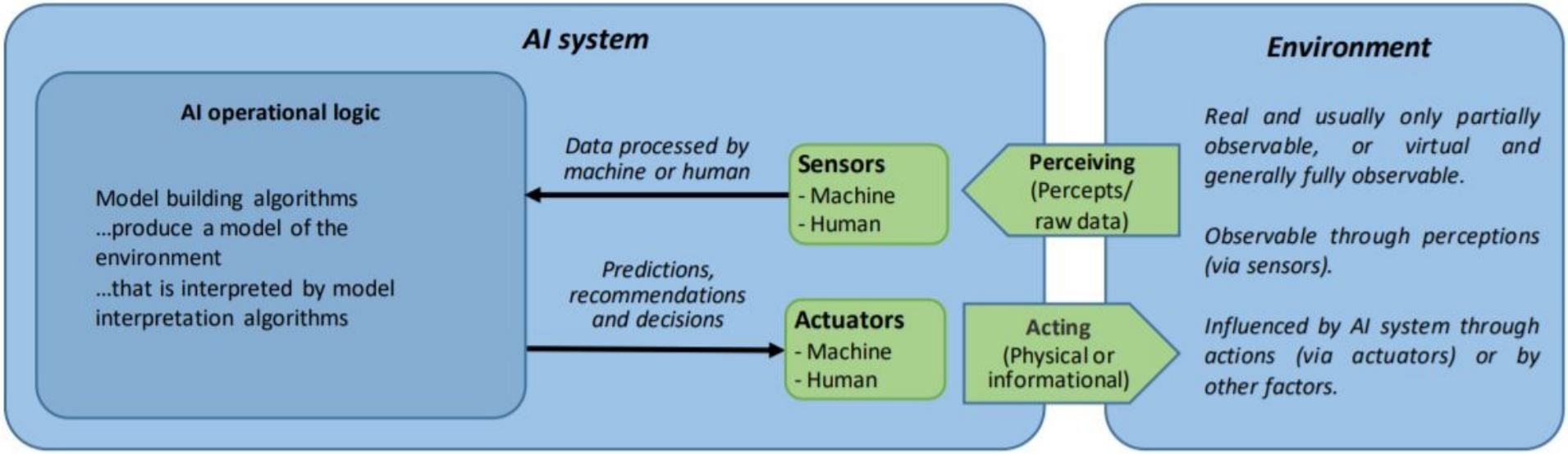
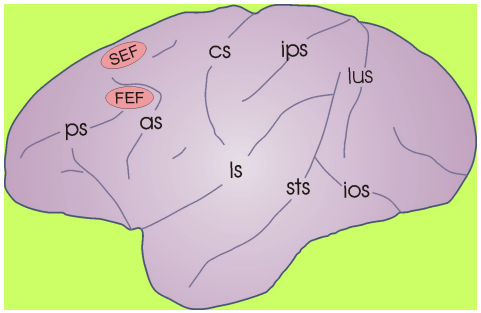
How neuroscience can advance artificial intelligence, and how artificial intelligence is helping the study of the brain

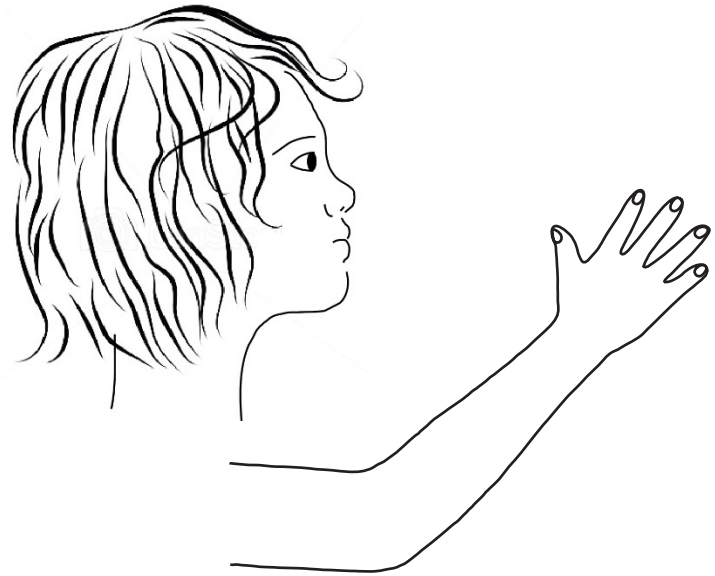
Human Intelligence



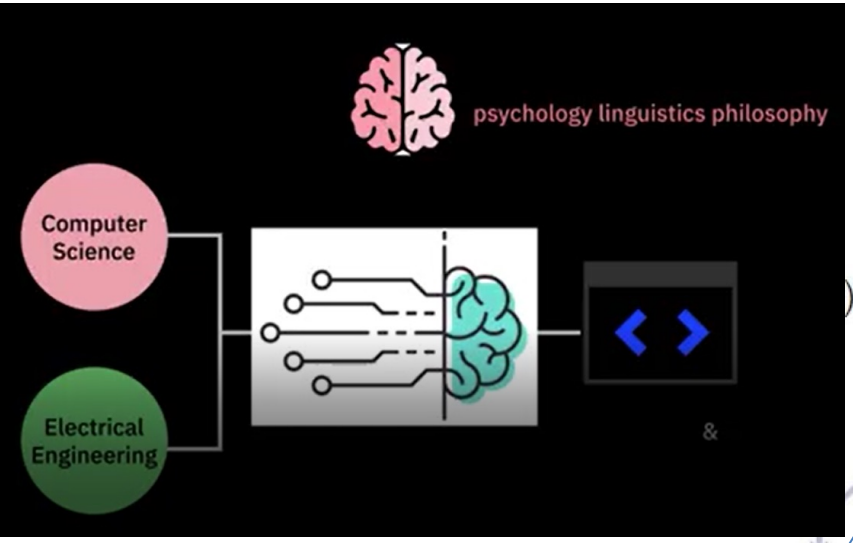
Some tasks of the Brain and of AI are similar….







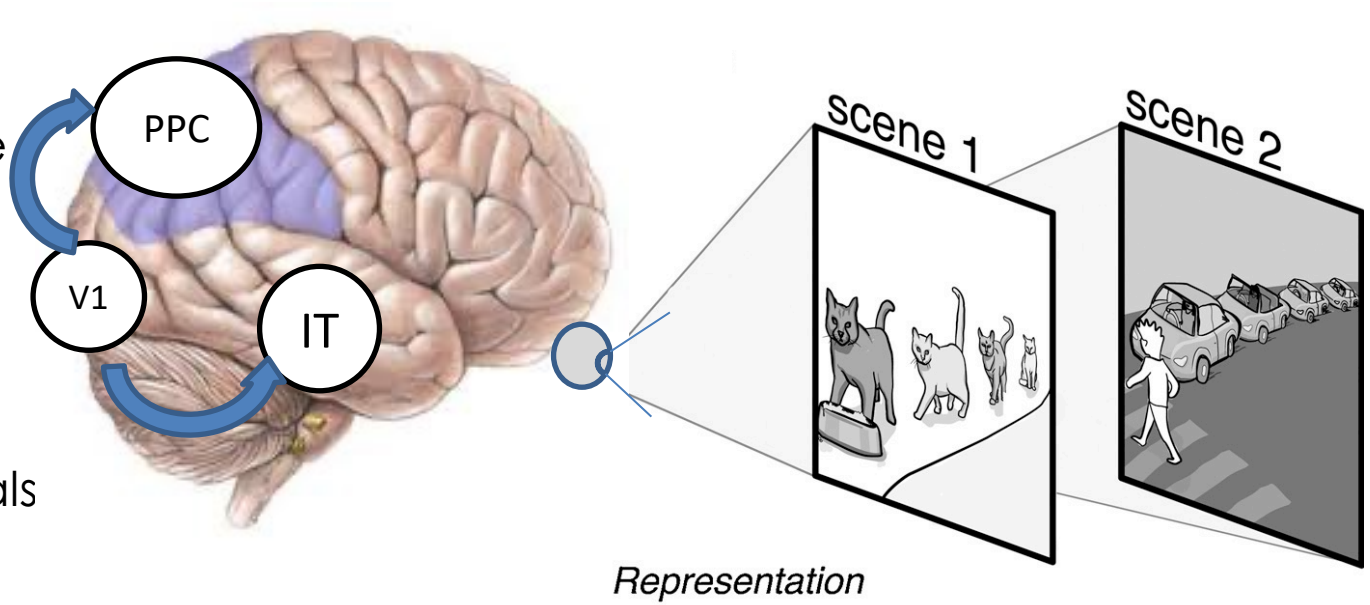
Neuroscience for AI



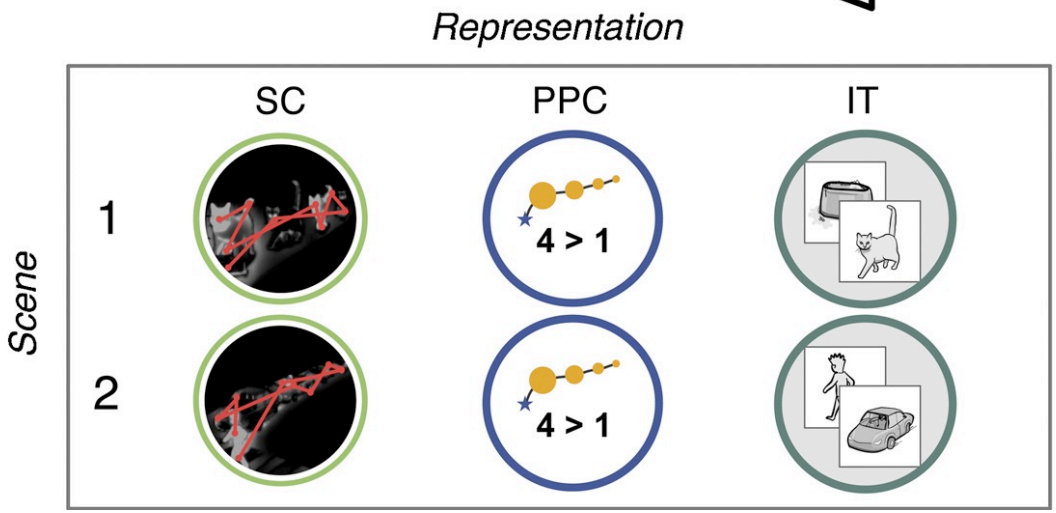
Untangling invariant object recognition
J DiCarlo and D Cox (2007)

Neuroscience for AI

- **PPC** constructs a saliency map of the various objects that facilitates scene understanding.

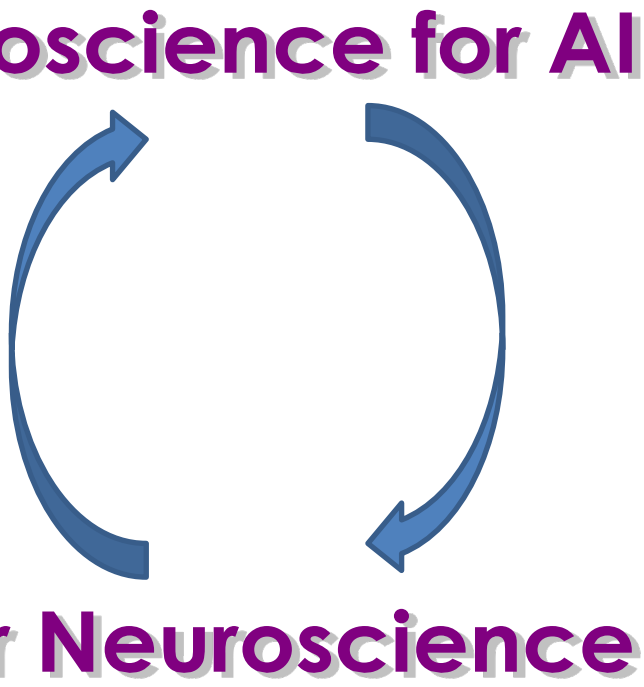


- **PPC** receives signals related to gaze position from subcortical gaze centers (**SC**) that help reconstruct the spatial relationships of the objects in the scene→ very important for action



Structure learning and the posterior parietal cortex Progress in Neurobiology 101717, 2020

The other way around



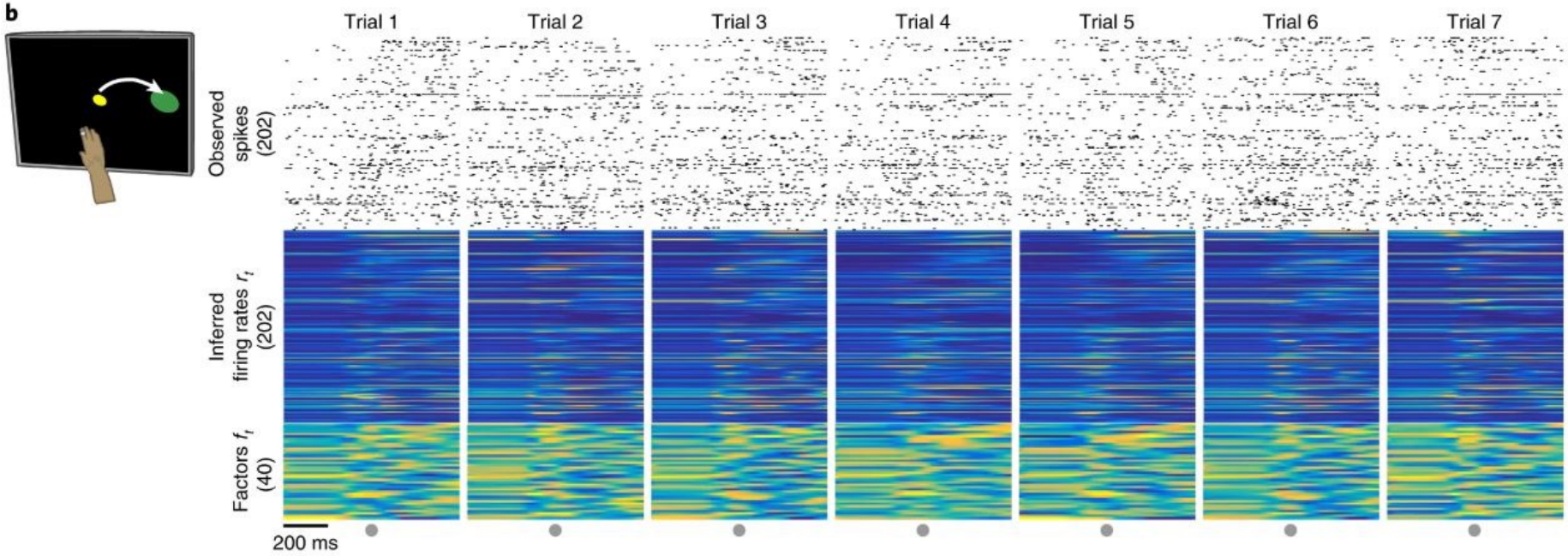
AI can identify patterns in large, complex data sets.

Modern Neuroscience techniques generate large, complex data sets.

The computational power of AI is used as a tool.

Developing and testing ideas about the brain computations

AI for Neuroscience



Non-linear RNNs can reproduce the complex temporal activity patterns of neural data (Pandarinath et al. *Nature Methods* **15**:805–815, 2018)

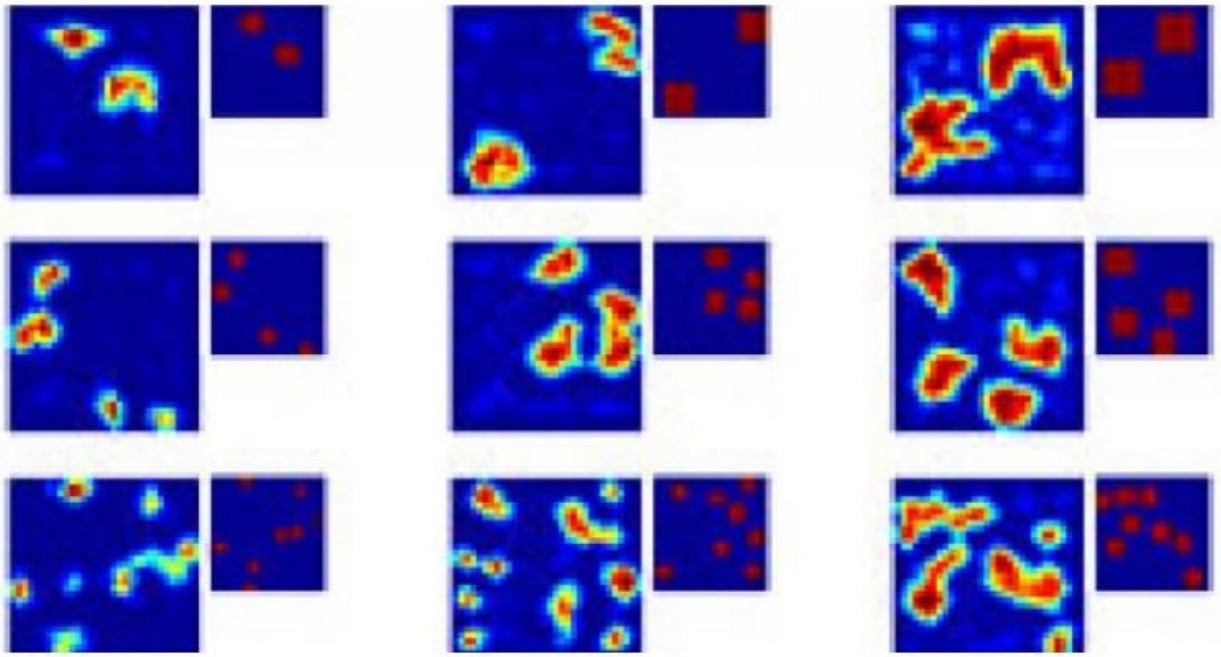
AI for Neuroscience

How learning occurs in human development?

Unsupervised learning

RNN observing the world i.e.receiving sensory input and creating its own internal representation without explicit training.
In humans , posterior parietal cortex (PPC) does It.

Development of basic numerosity sensitivity similar to that of infants.



Stoianov, I. & Zorzi, M. (2012)
Emergence of a "visual number sense" in hierarchical generative models.
Nature Neuroscience 15:194–96.

Neuromorphic approach as a bridge

Neuroscience for AI: Brain-inspired hardware, such as neuromorphic boards, provide excellent substrate to test large-scale neural networks.

AI for Neuroscience: Complex NNs are expensive to run on traditional computers, requiring lot of time and power to run.

- Networks architectures inspired to our brain, ready for dynamic interaction with the surrounding environment (industrial automation, human-robot interactions, smart sensors)
- Real Time
- Ultra low power consumption
- Fully Asynchronous

- Testing in silico realistic brain networks (virtual lesions, disease models)
- Bidirectional connection between electronics and biological tissue
- Advance in BCI technologies

Neuromorphic approaches:

- Digital Neuromorphic: clock driven, faster than biological counterpart, best for modeling
- Mixed Analog-Digital: fully asynchronous, more realistic, low power

Future directions

-brains can easily adapt to very different environments and new tasks over lifetime, NNs are still highly specialized

-Attention, memory, learning mechanism in NNs can be improved by more biologically plausible implementations

-Brain is a dynamical system changing even without the input, in resting-state, while machine-learning models are mainly "static"

Next-generation AI based on better understanding of brain functioning including plasticity, attention, memory, reward processing, motivation, and beyond, while approaching both brain and AI as stochastic dynamical systems rather than just predictors.

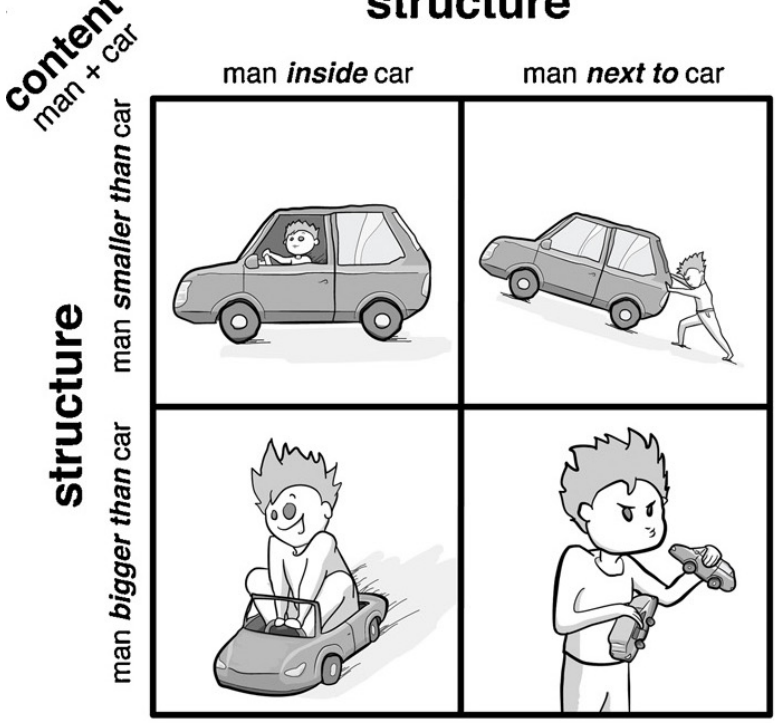
Future directions

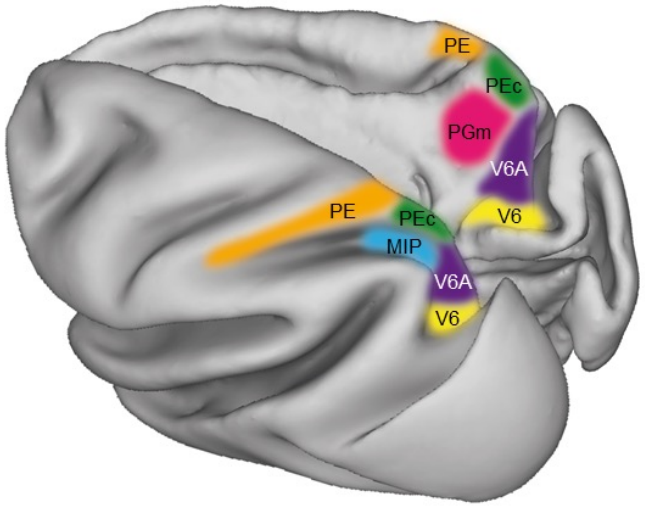
Deep learning AI algorithms are good at object recognition, but fail to identify the spatial relationship of multiple objects in a scene and are poor in organizing action…in dynamic contexts.

Parietal cortex (PPC) in higher mammals and primates

Is crucial for the encoding of space and the relationship of the various objects between themselves, but also with our body parts.

Next-generation AI could implement computational principles of the parietal cortex to enable assistive devices with the capacities of spatial perception (scene understanding) and action planning.



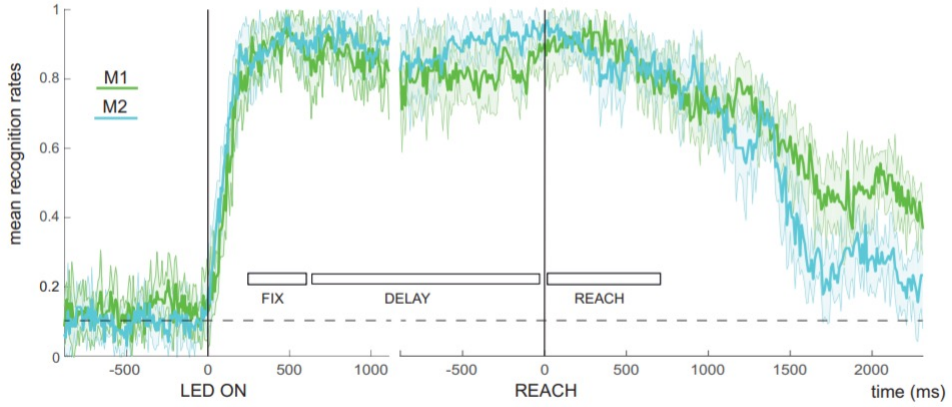


Neural decoding from PPC for BCI applications

Reach movements in different spatial locations

Data acquisition

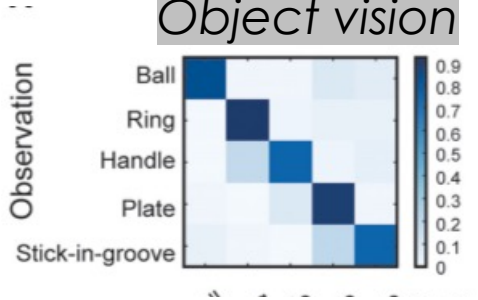
Decoding (ML approaches)



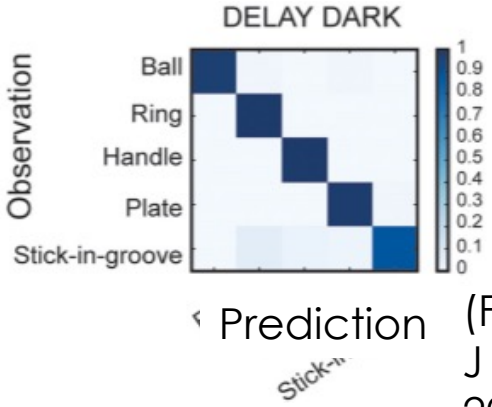
Accuracy in detecting the correct spatial position over the time
(Filippini et al. Cell reports 2018)

Type of grips (grasping)

Object vision



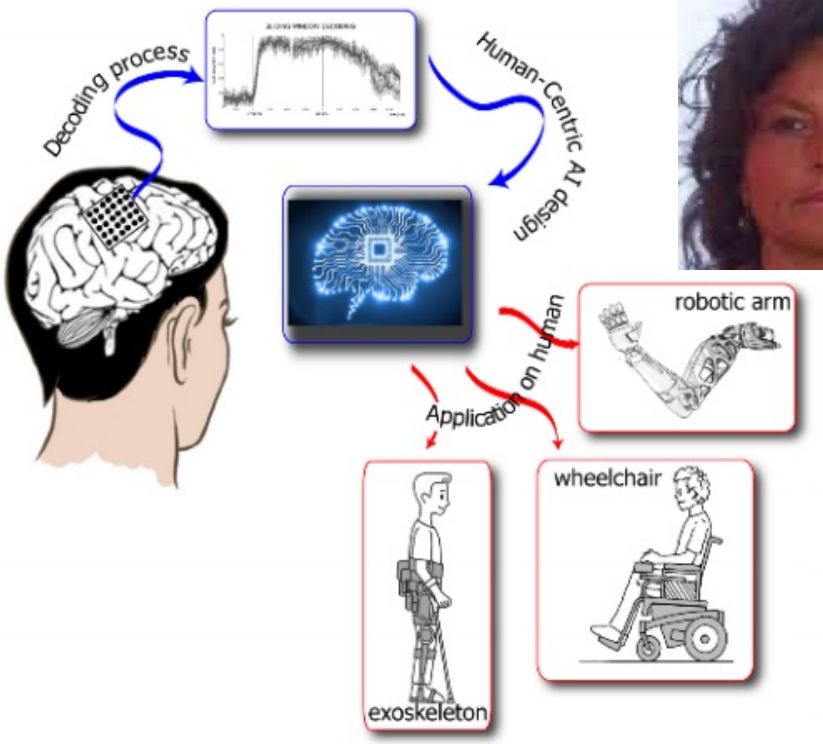
Intention to grasp



(Filippini et al. J Neuroscience 2017)

Funded projects

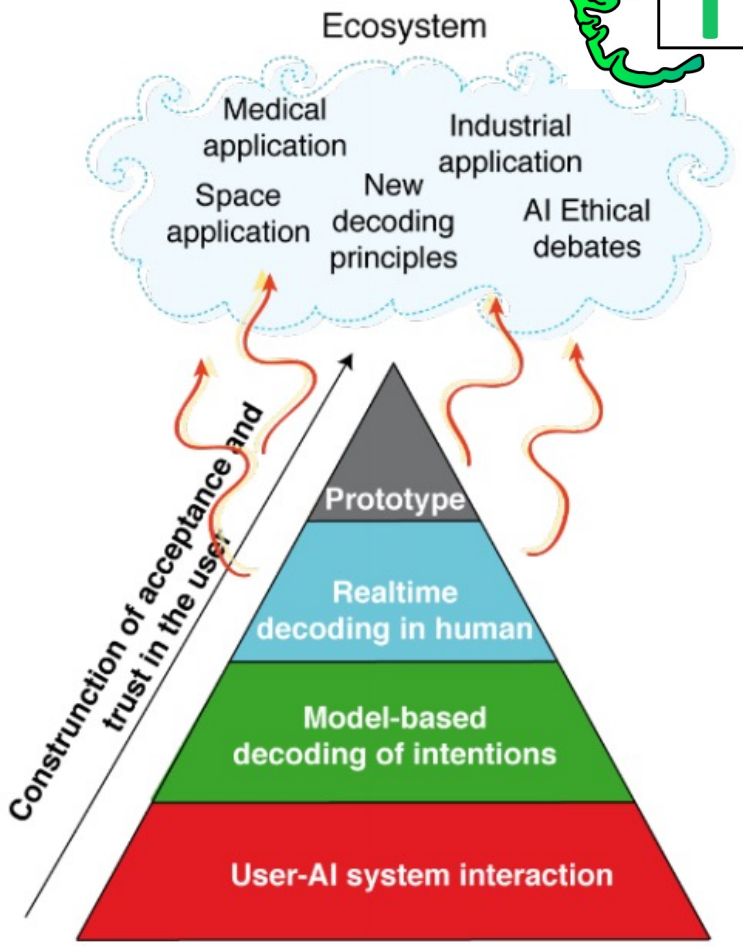
H2020-EIC-FETPROPROACT
Human Centric AI – MAIA
Multifunctional, **A**daptive and **I**nteractive AI system for **A**cting in multiple contexts



- Inputs: brain and behavioral signals
- Human-centric bidirectional decoder
- Multiple actuators

(H2020-EIC-FETPROACT-2019 n.951910-MAIA)

Funded projects



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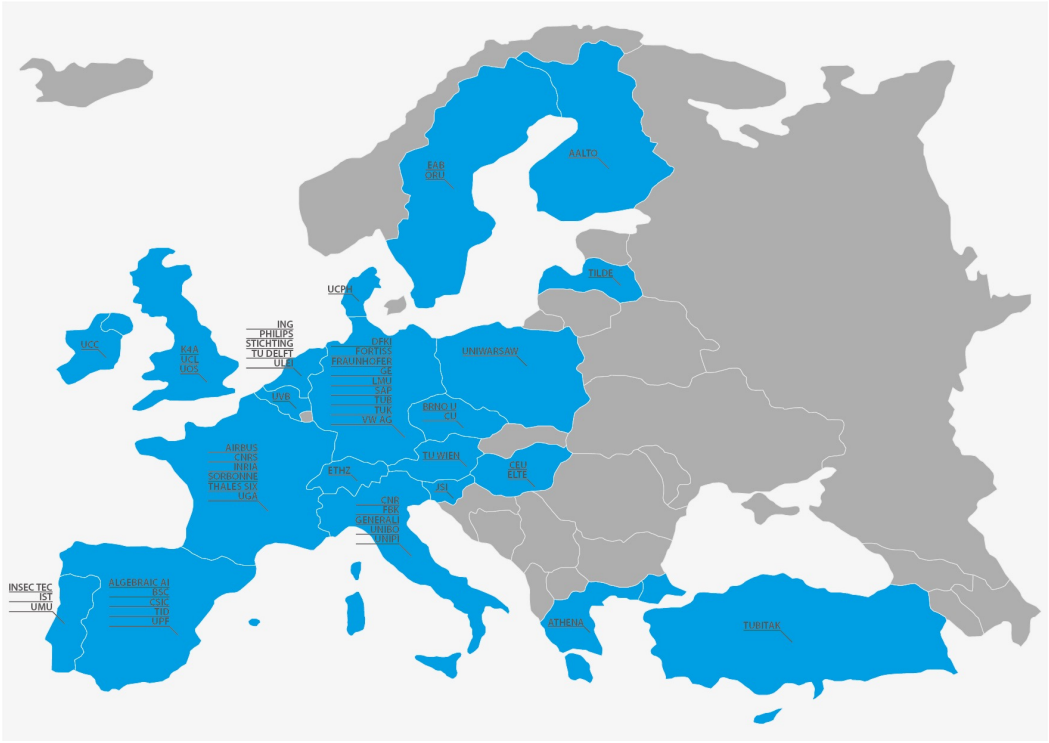
(**H2020-EIC-FETPROACT-2019 n.951910-MAIA**)

Funded projects

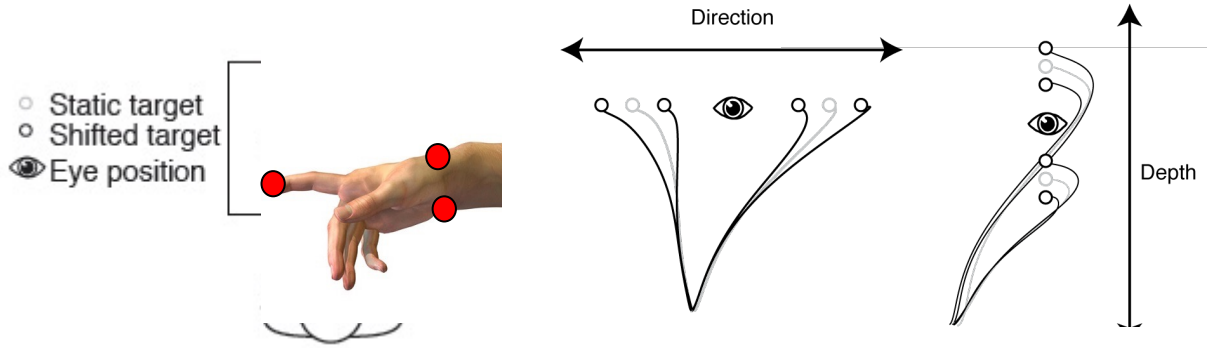
HUMANE AI NET



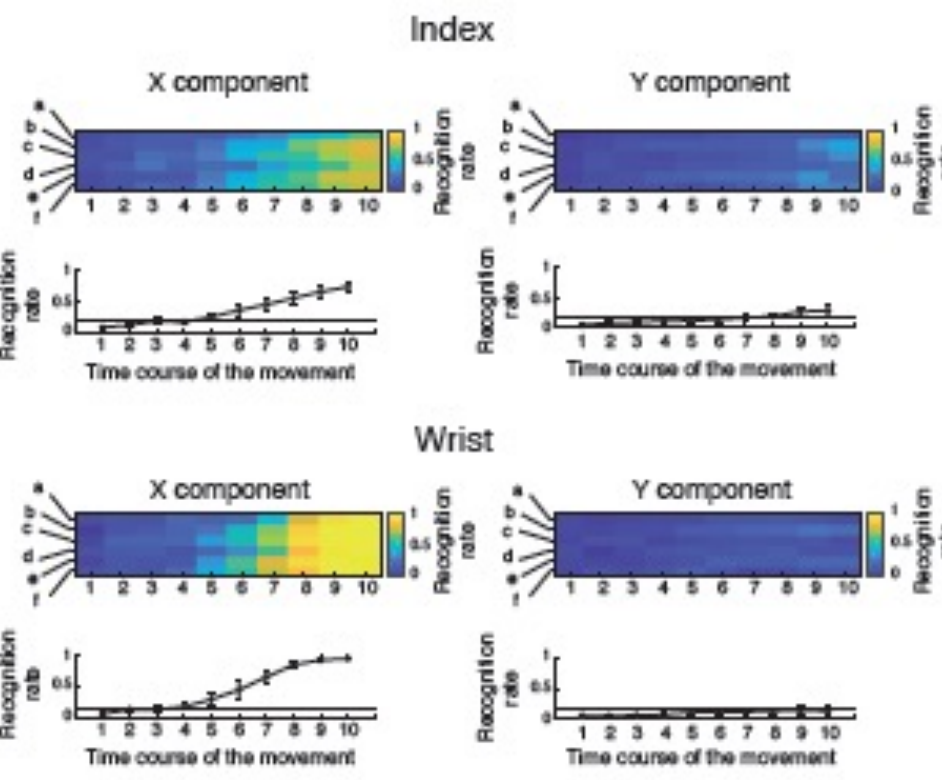
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 761758.

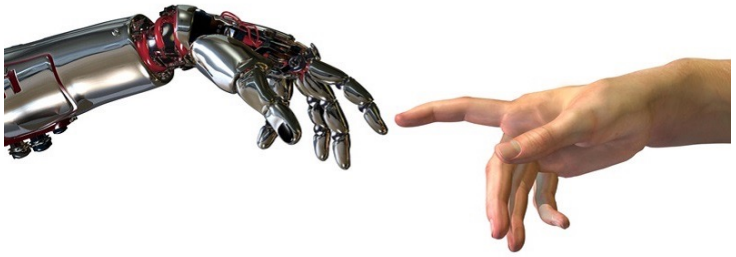
Funded projects

HUMANE AI NET



Prediction of static and perturbed reach goals from movement kinematics





Improving **human-AI interactions** by predicting the purpose of human movements

In collaboration with German Research Center for Artificial Intelligence (DFKI).

- Thanks for your attention