Brain Based Architectures for Advanced Robotics

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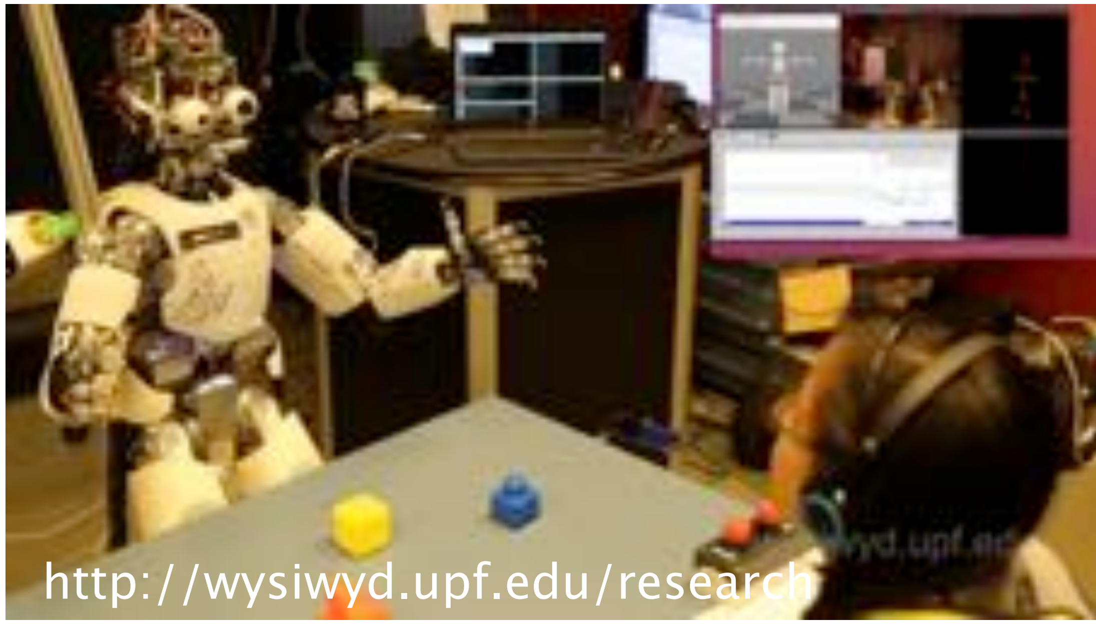


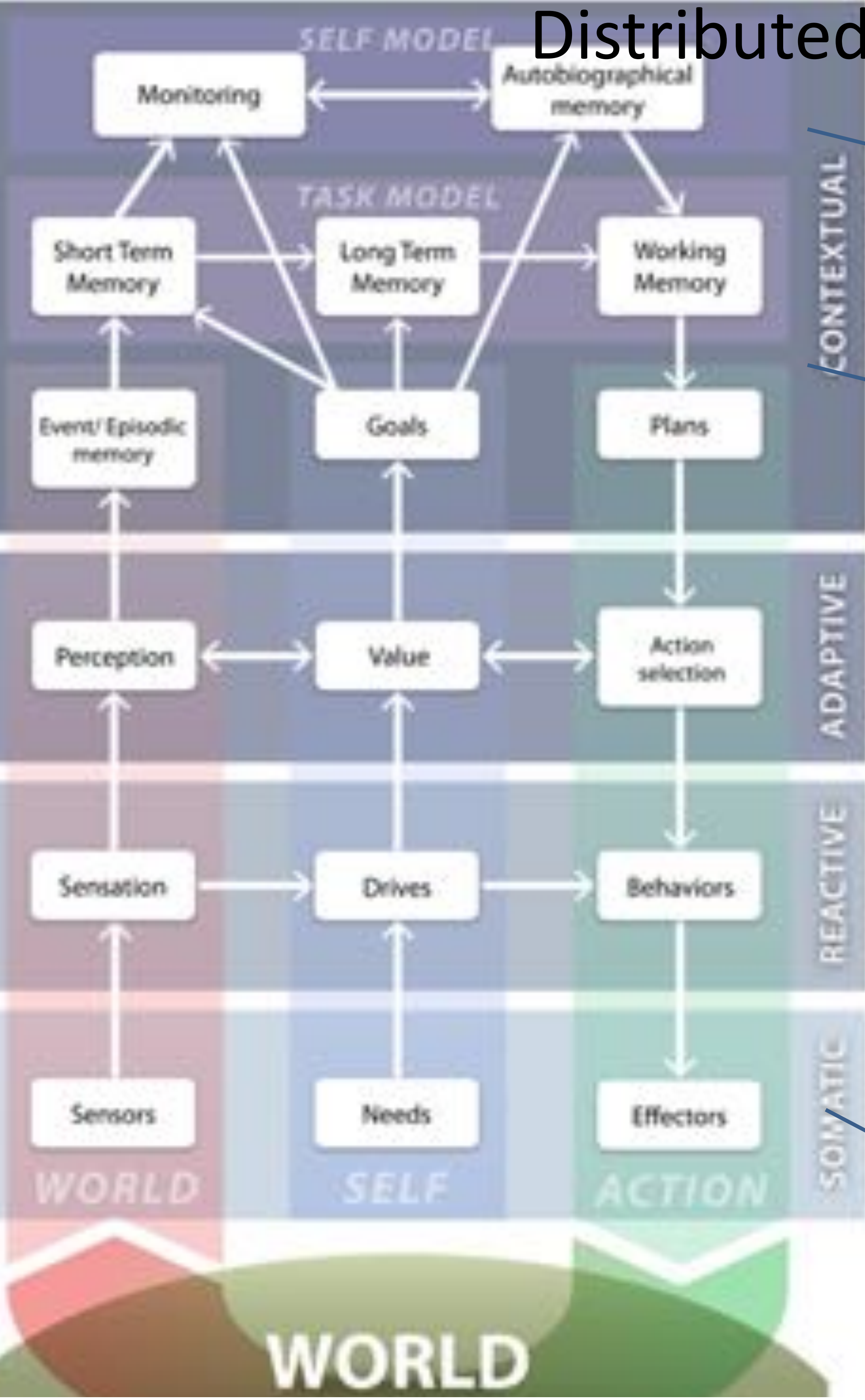
Self:
Interactive human assisted body map acquisition

Do you speak Robotese?

Self-Other / communication:
Object recognition, Pro-active labelling

Self-Other / communication:
Invariant object/action naming (nouns, verbs)

Distributed Adaptive Control



autonoetic memory, **consciousness**

goal-oriented policies from sequence learning on state-affect-action triads (model based RL)

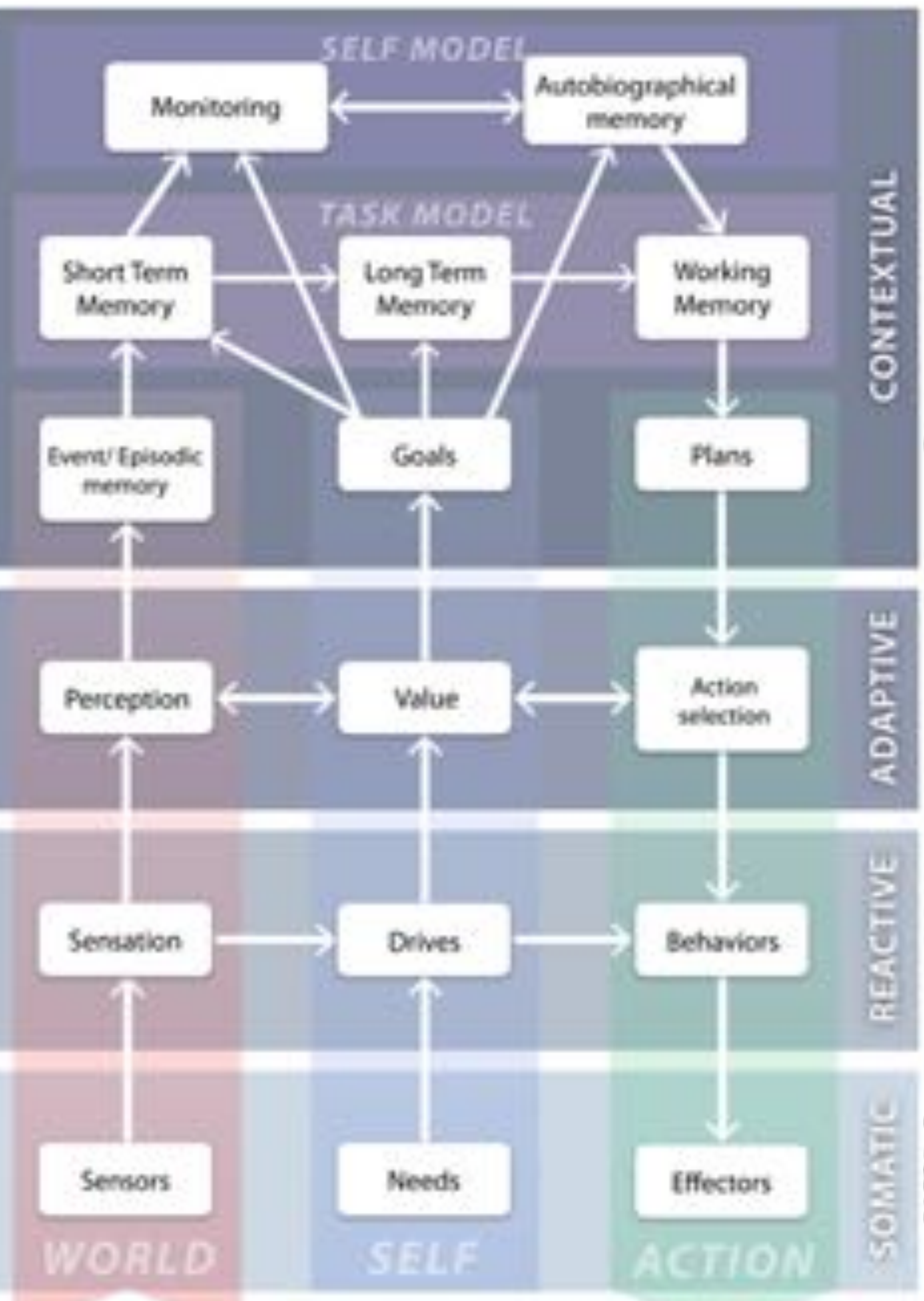
state space acquisition of agent-environment interaction from dynamics of the reactive level and action shaping (deep learning & model free RL)

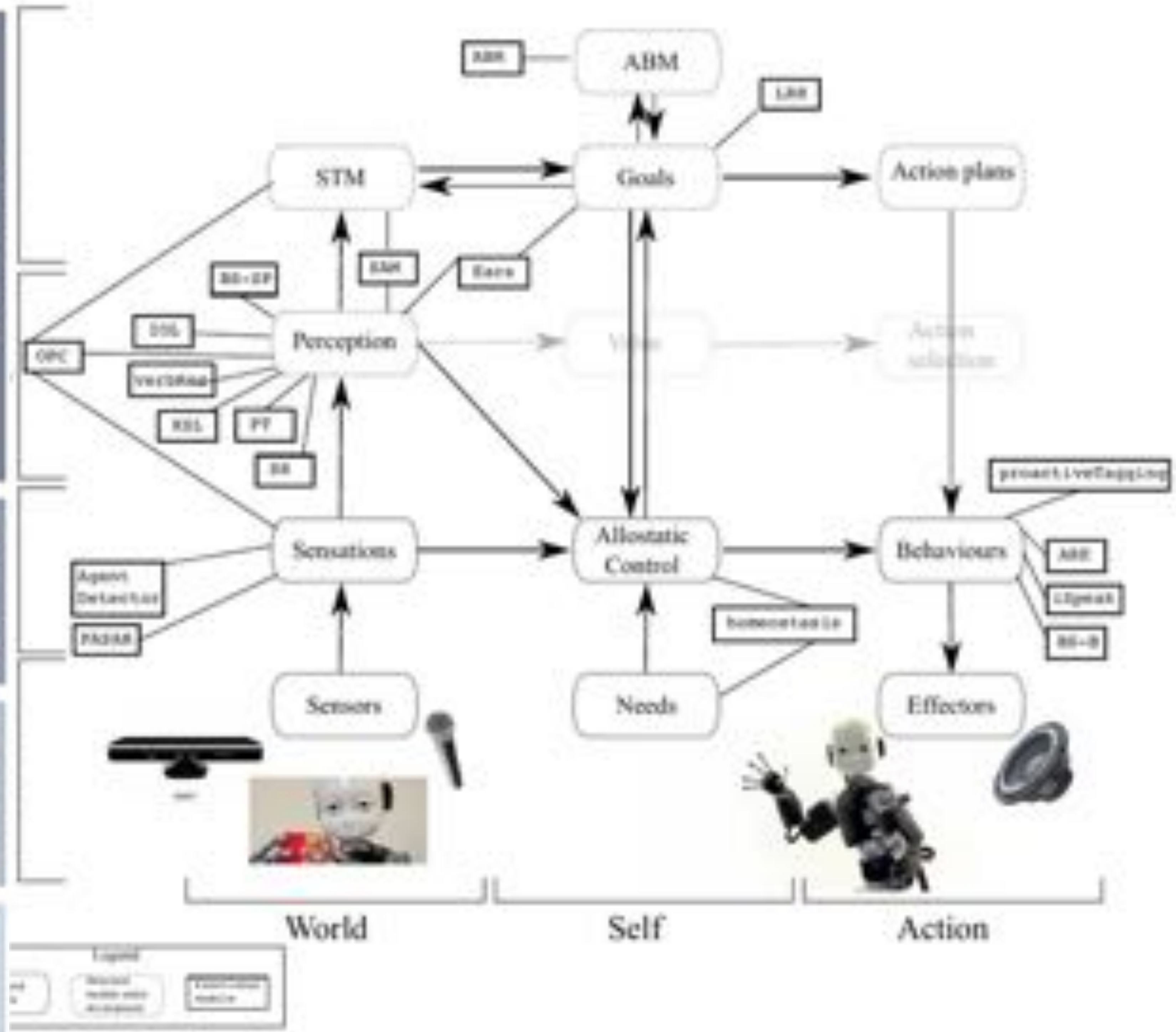
reactive interaction with the environment through **drive regulation, homeostasis, allostasis**

the **physical agent** with sensors, effectors, intrinsic dynamics and needs

Verschure et al 1993;1998 NN; 2003 Cog Sci; Nature; 2012 Biol. Insp.Cog.Arch. 2013 IEEE Expert; 2014/2016 TrRoySoc

Robotese-DAC





Verschure (2012) BICA/IEEE
Verschure (2016) Phil Tr. Roy Soc B
Lallee et al (2015) Pal. J.Beh.Rob; Robotics
Moulin-Frier et al (Submitted)

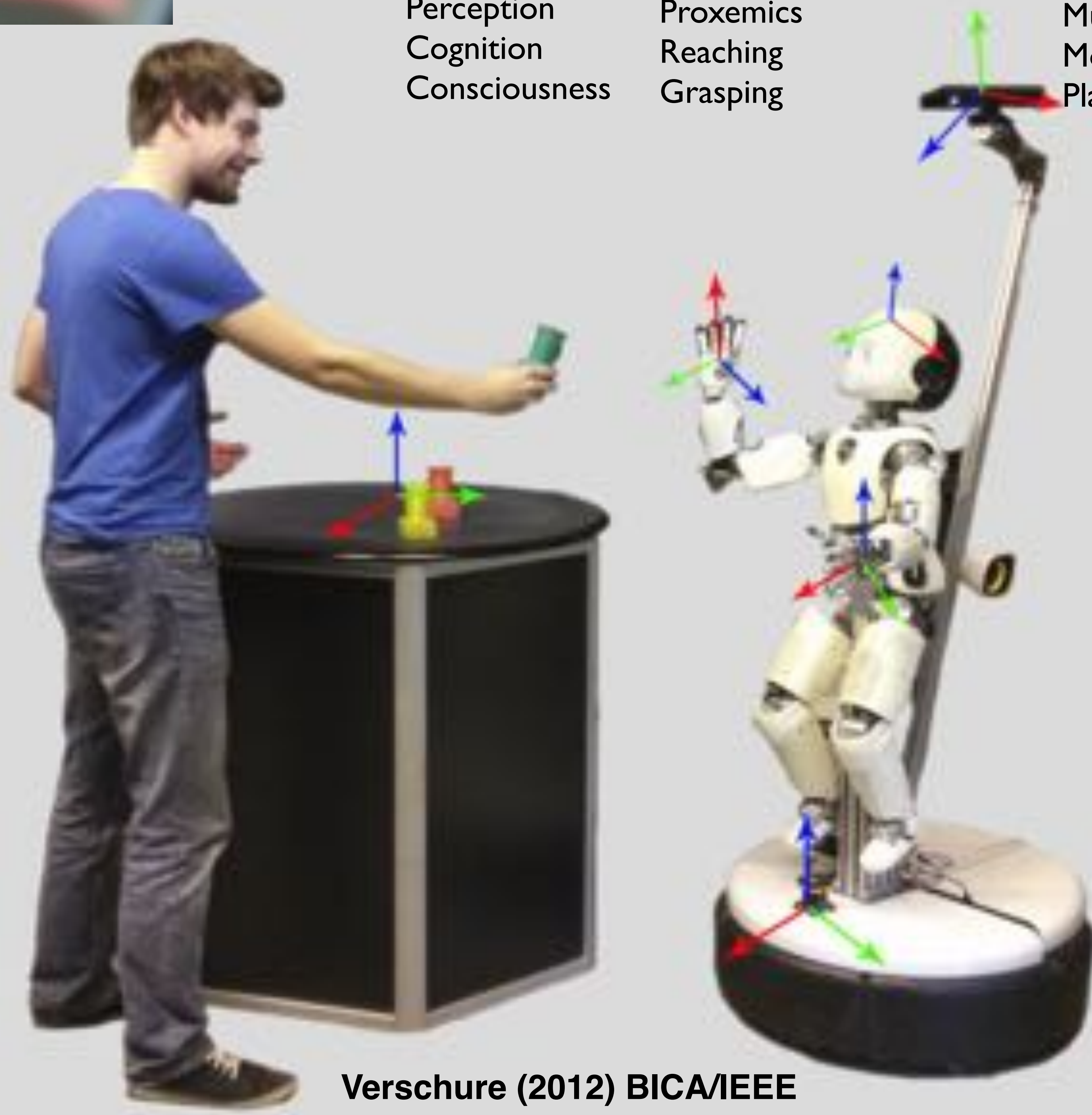
6 machines @4 cores/32GB RAM.
~20MB/s communication; 50 yarp modules

What You Say Is What You Did

- Motivation
- Personality
- Emotion
- Learning
- Perception
- Cognition
- Consciousness

- (Shared) attention
- Mind reading
- Autobiographical memory
- Navigation
- Proxemics
- Reaching
- Grasping

- Face/gesture recognition
- Natural language interaction
- Compliance
- Touch
- Multiple frames of reference
- Motor control
- Planning ……



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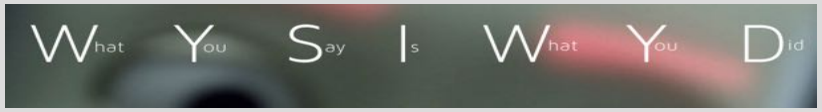
Robotics = Synthetic Psychology



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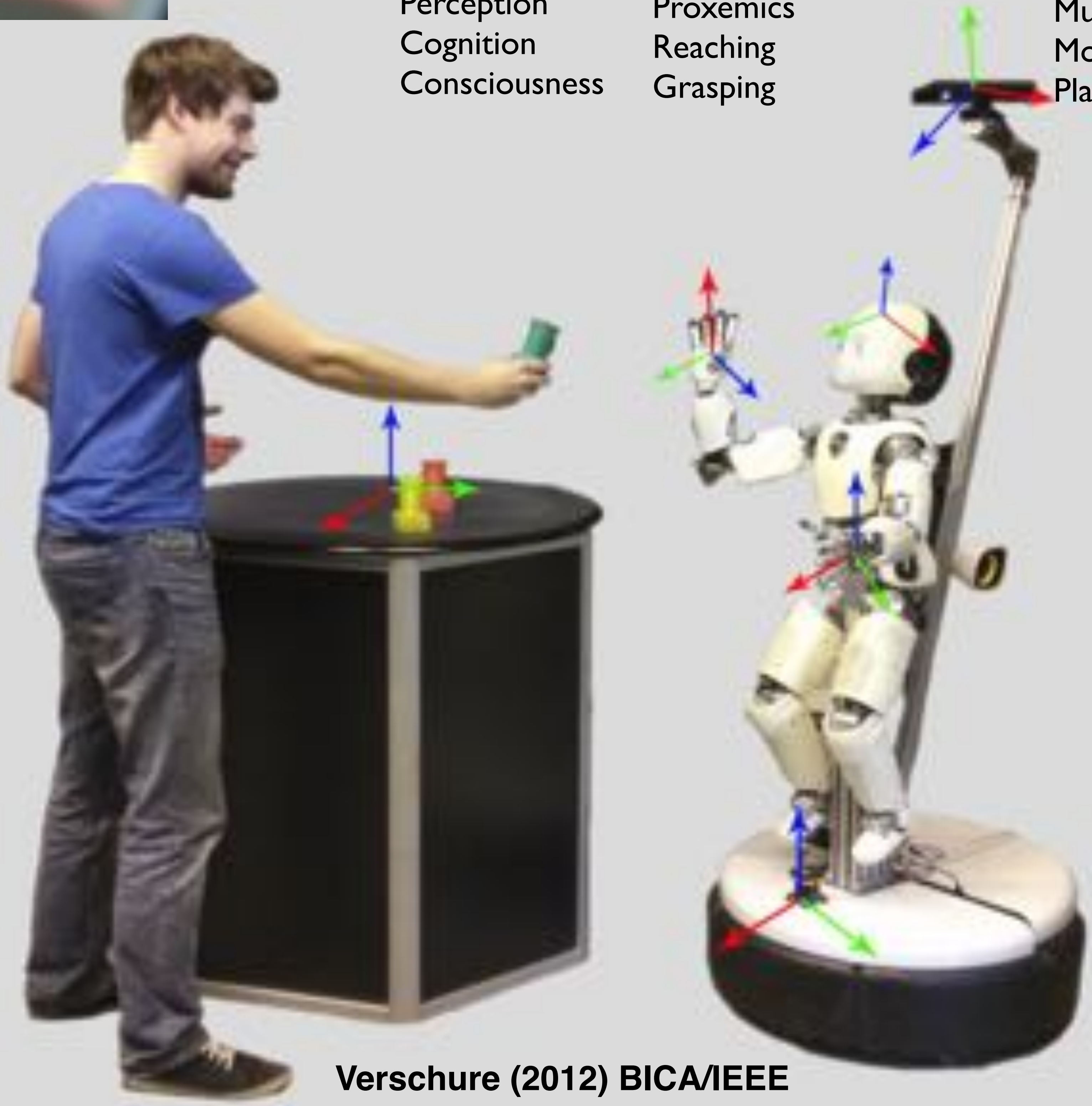

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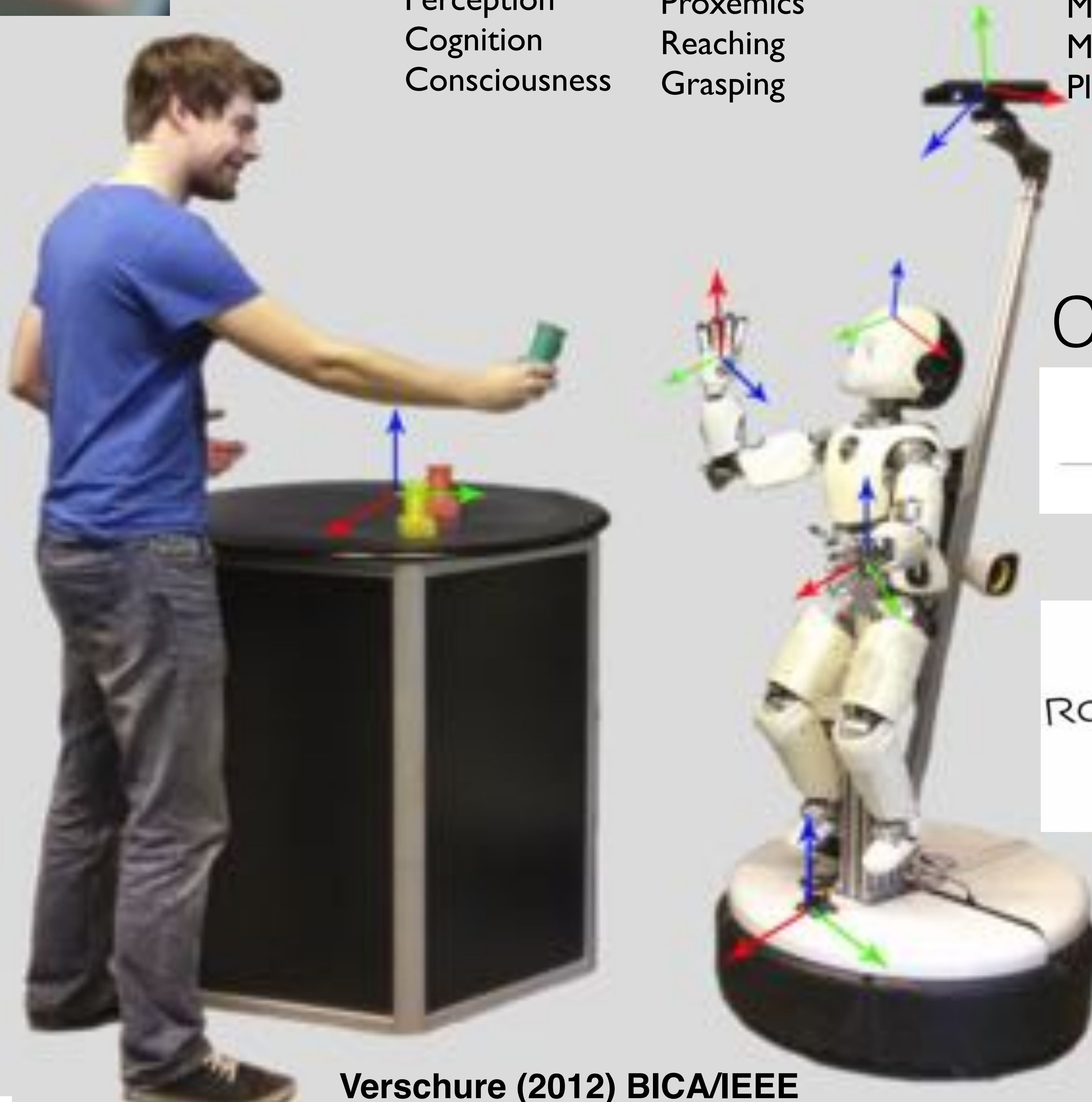

efAA

synthetic forager

GoalLeader

CSA:

Convergent Science Network of biomimetic and biohybrid systems

Robot Companions for Citizens

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Verschure (2016) Phil Tr. Roy Soc B
Lallee et al (2015) Pal. J.Beh.Rob; Robotics
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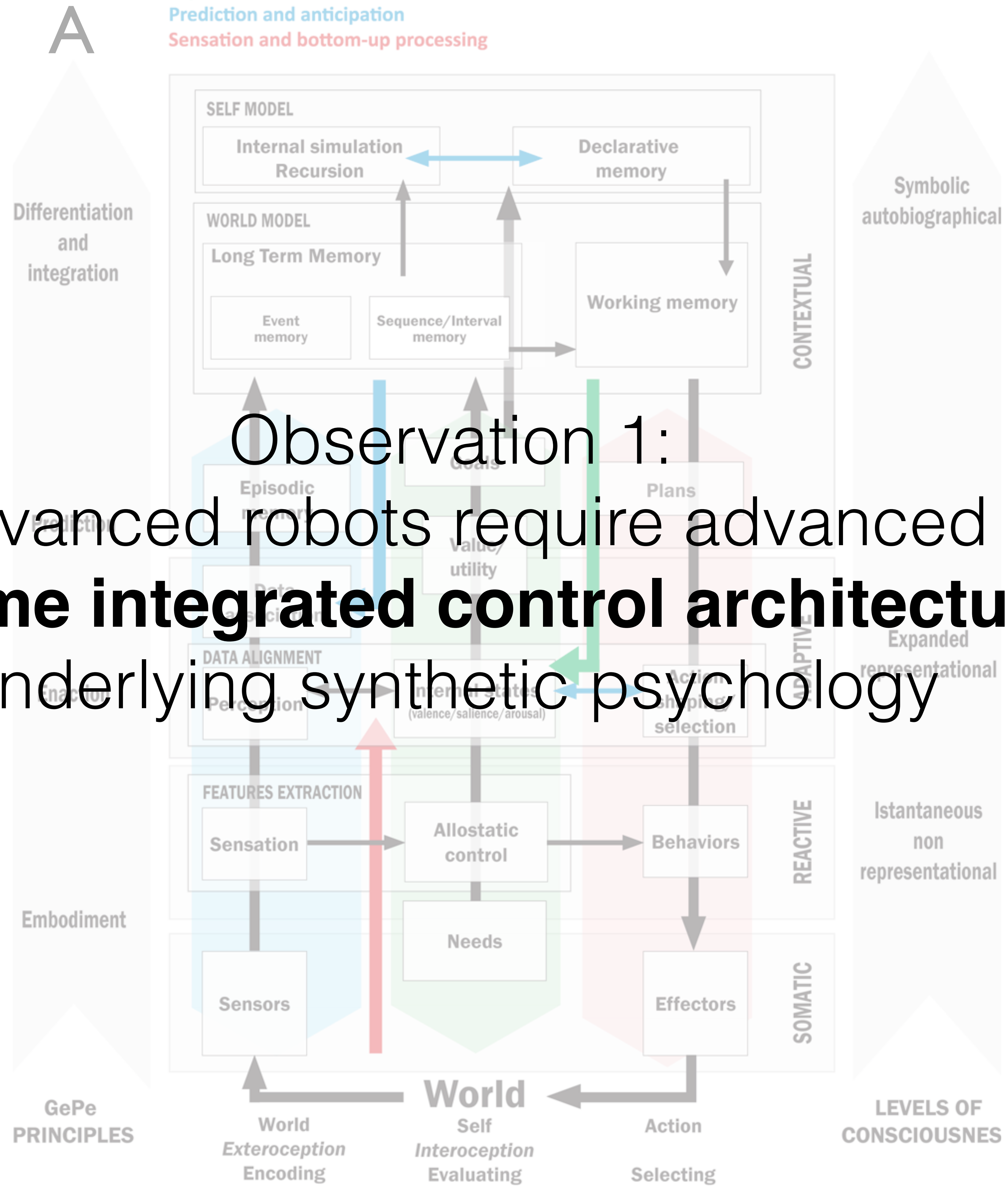


Observation 1:
Advanced robots require advanced **real-time integrated control architectures** underlying synthetic psychology

Verschure 1992 Rob Aut Sys; 2003 Nature; 2012 Biol. Insp.Cog.Arch. 2013 IEEE Expert; 2014;2016 Phil Tr. Roy Soc

psyche

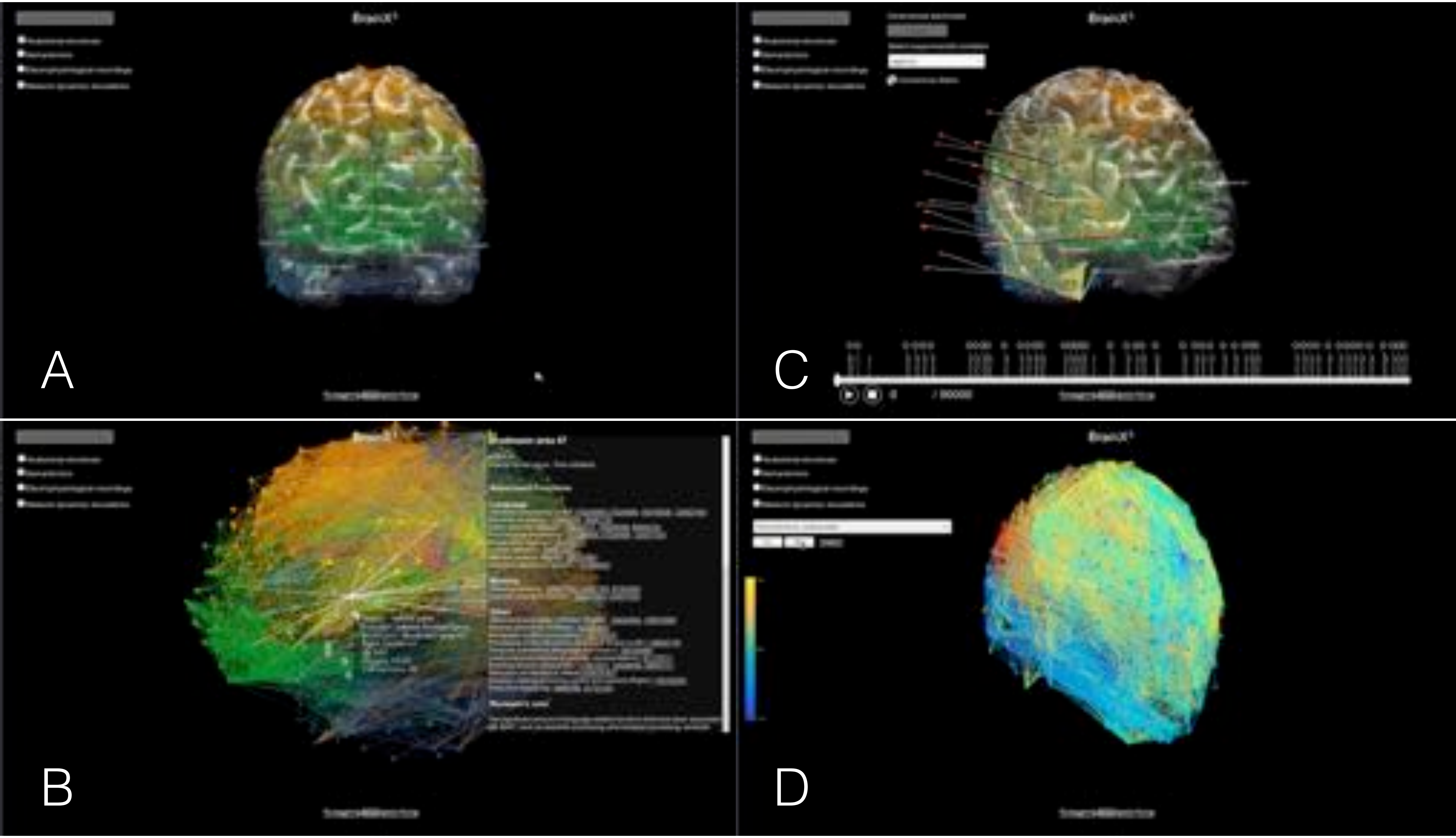

psyche
flesh
Herculano-Houzel

psyche

flesh

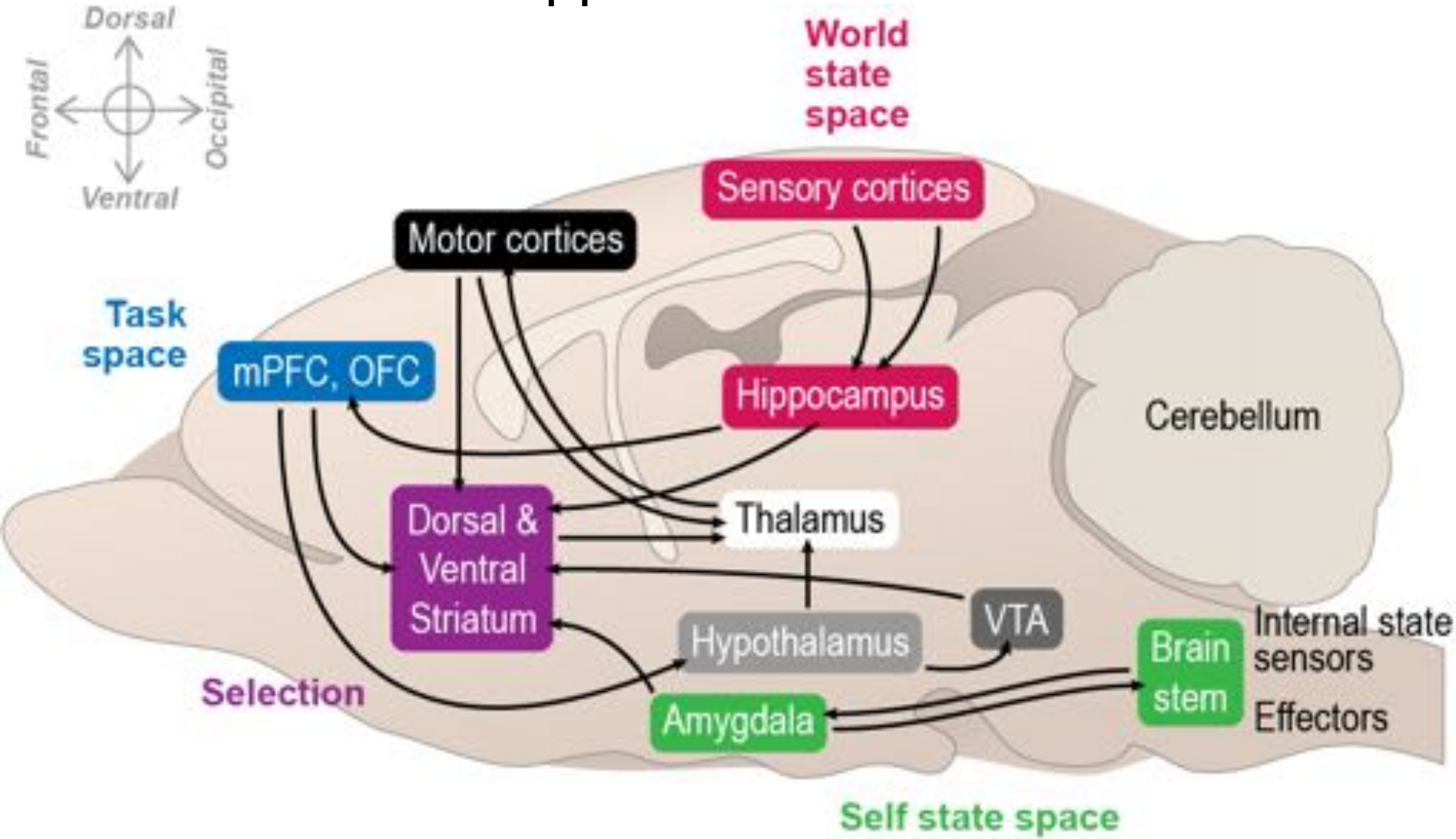
Herculano-Houzel

Towards an infrastructure of whole brain modeling: BRAINX3.com



The challenge of WHOLE BRAIN analysis & synthesis

Distributed Adaptive Control: Mapped to the brain

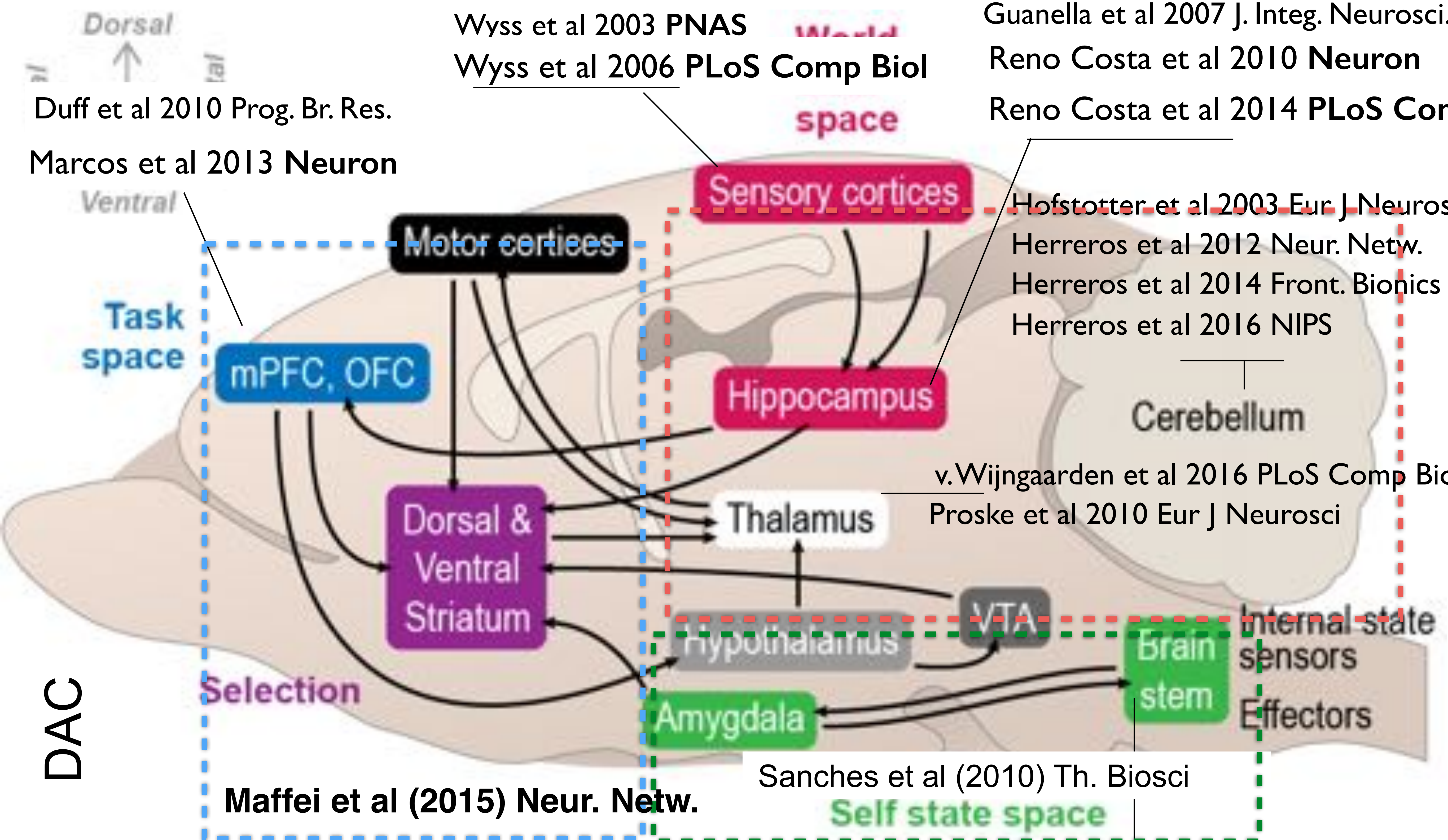


Verschure et al (2014) Phil.Tr.Roy.Soc B

Sanchez et al (2000) Neur. Comp.
Wyss et al 2003 **PNAS**
Wyss et al 2006 **PLoS Comp Biol**

Guanella et al 2007 J. Integ. Neurosci.
Reno Costa et al 2010 **Neuron**
Reno Costa et al 2014 **PLoS Con**

Duff et al 2010 Prog. Br. Res.
Marcos et al 2013 **Neuron**



Hofstotter et al 2003 Eur J Neuros
Herreros et al 2012 Neur. Netw.
Herreros et al 2014 Front. Bionics
Herreros et al 2016 NIPS

v. Wijngaarden et al 2016 PLoS Comp Bio
Proske et al 2010 Eur J Neurosci

DAC

Maffei et al (2015) Neur. Netw.

Sanches et al (2010) Th. Biosci

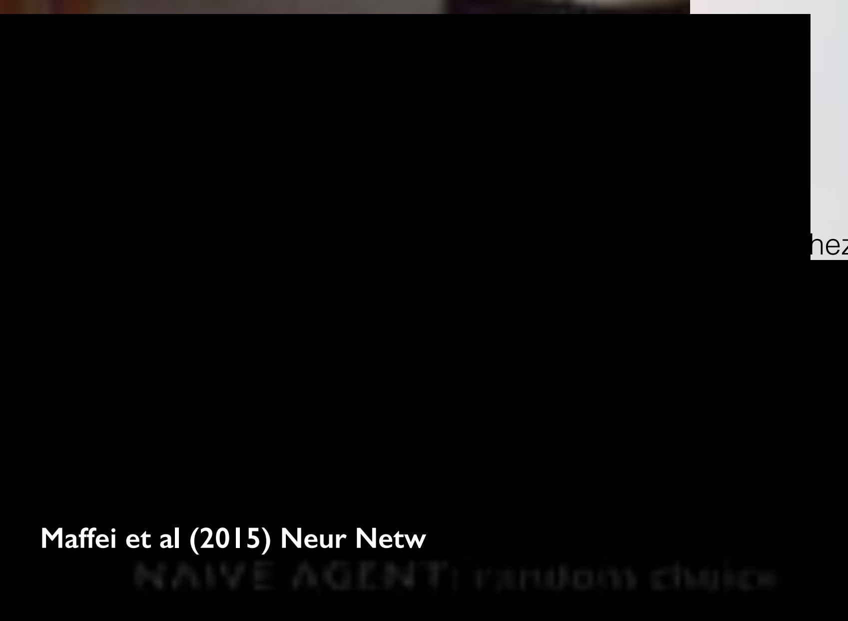
Verschure et al (2003) Nature
Verschure et al (2014; 2016) Phil.Tr.Roy.Soc.B

Guanella et al (2006; 2007) ICANN; J. Integ. Neurosci.

Reno Costa et al (2010;2013) Neuron, PLoS Comp Biol

hez-Fibla, et al (2011) IROS

Lallee et al 2014 HRI



Maffei et al (2015) Neur Netw

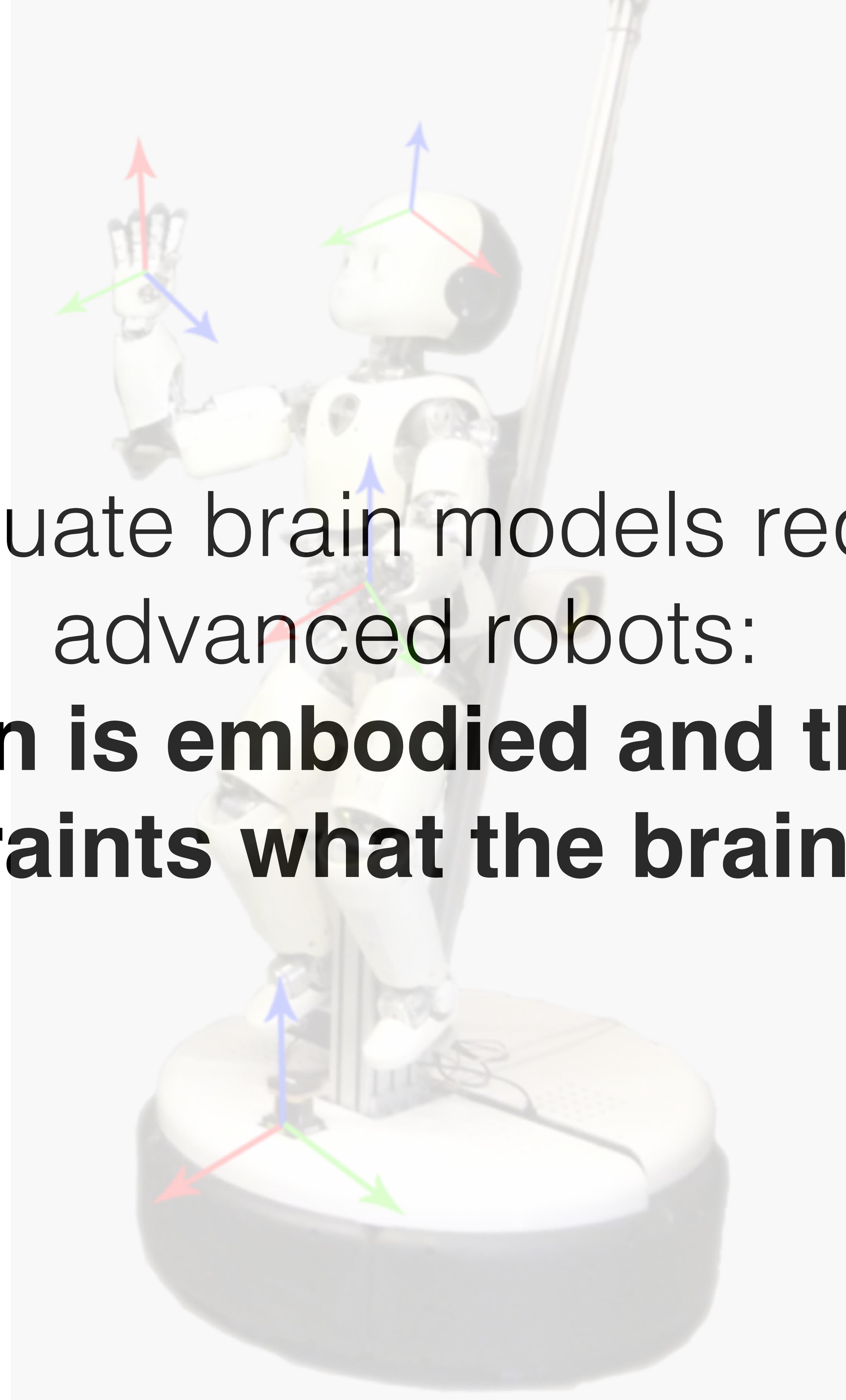
Mathews et al (2009) IROS

Herreros et al 2012 Neur. Netw.

Herreros et al 2016 NIPS

Verschure et al (1996) RAS

Models of the brain should capture: Anatomy, physiology and behavior, i.e. they must be embodied.



Adequate brain models require advanced robots:

The brain is embodied and the body constraints what the brain does

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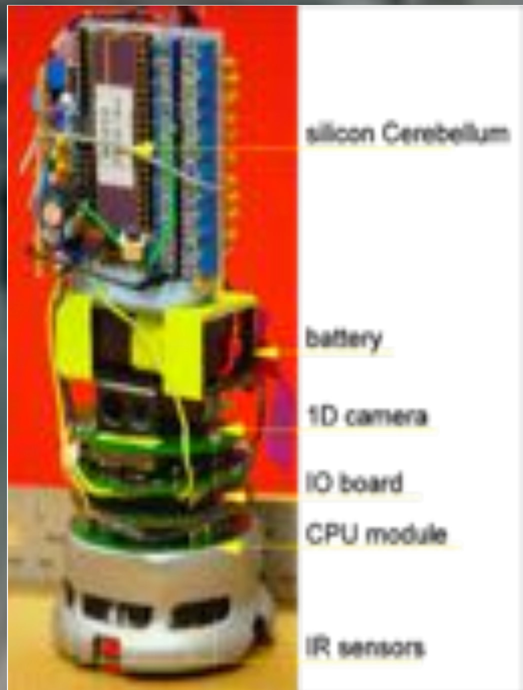
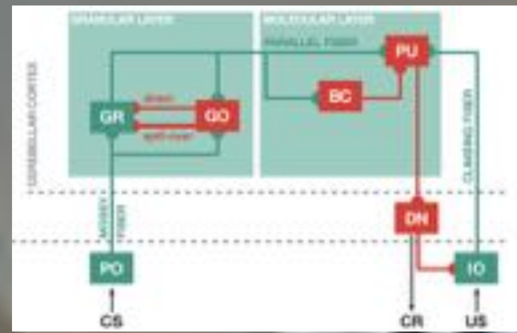
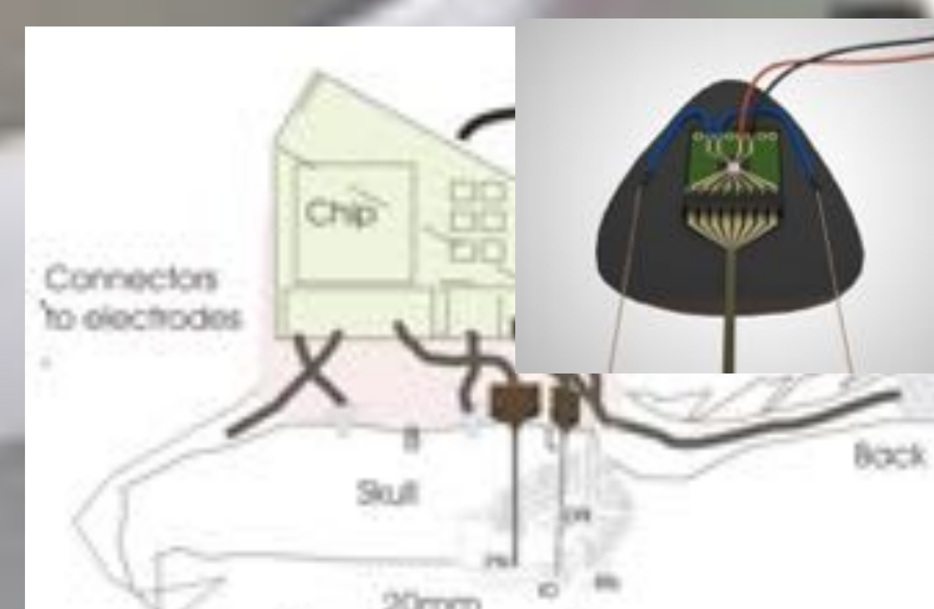




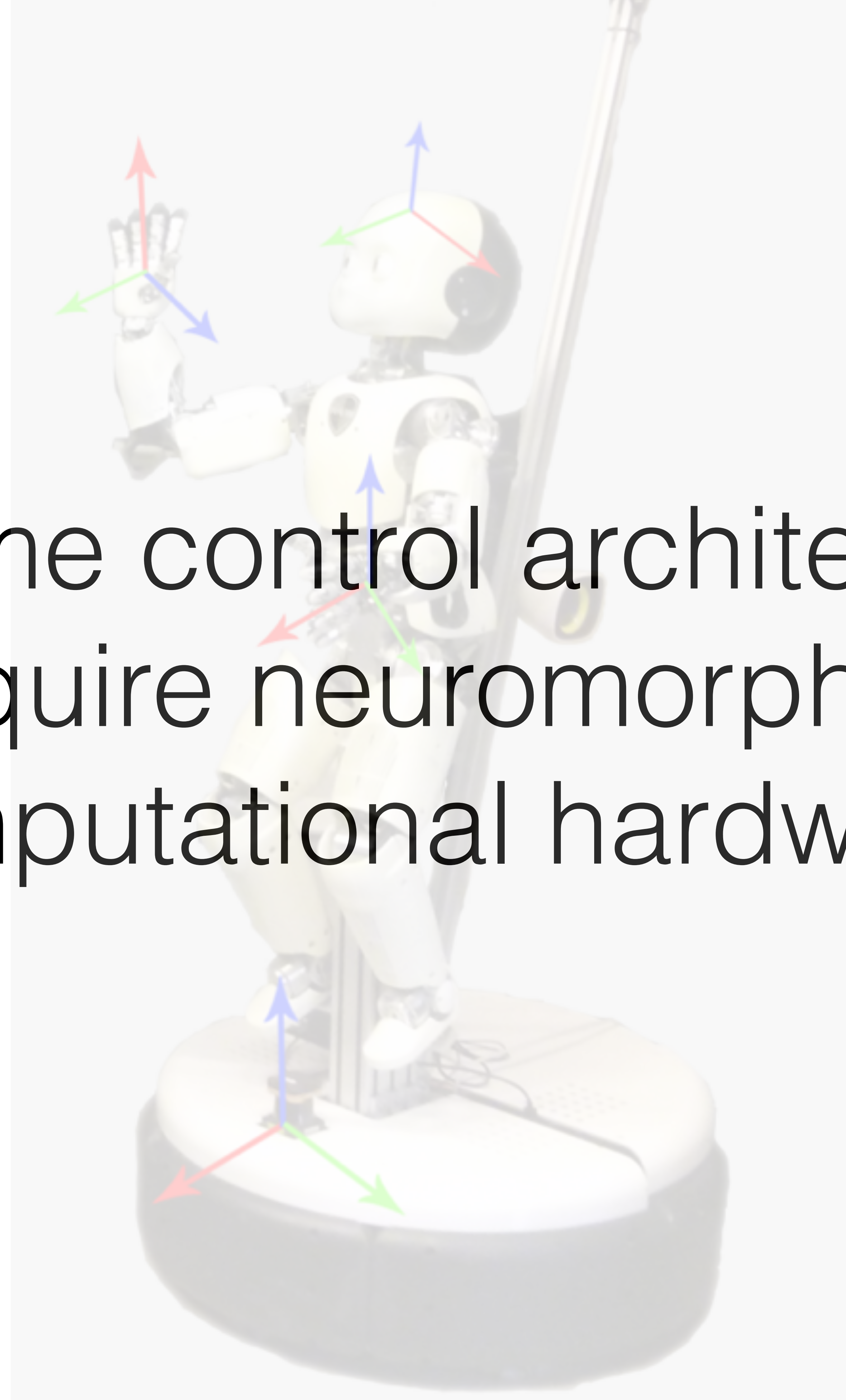
2002: The silicon cerebellum



Hofstotter et al (2005) NIPS

Verschure & Mintz (2000); Hofstotter et al (2003) Eur. J. Neurosci

Herreros et al. (2014) Front. Bioeng.



Real time control architectures require neuromorphic computational hardware

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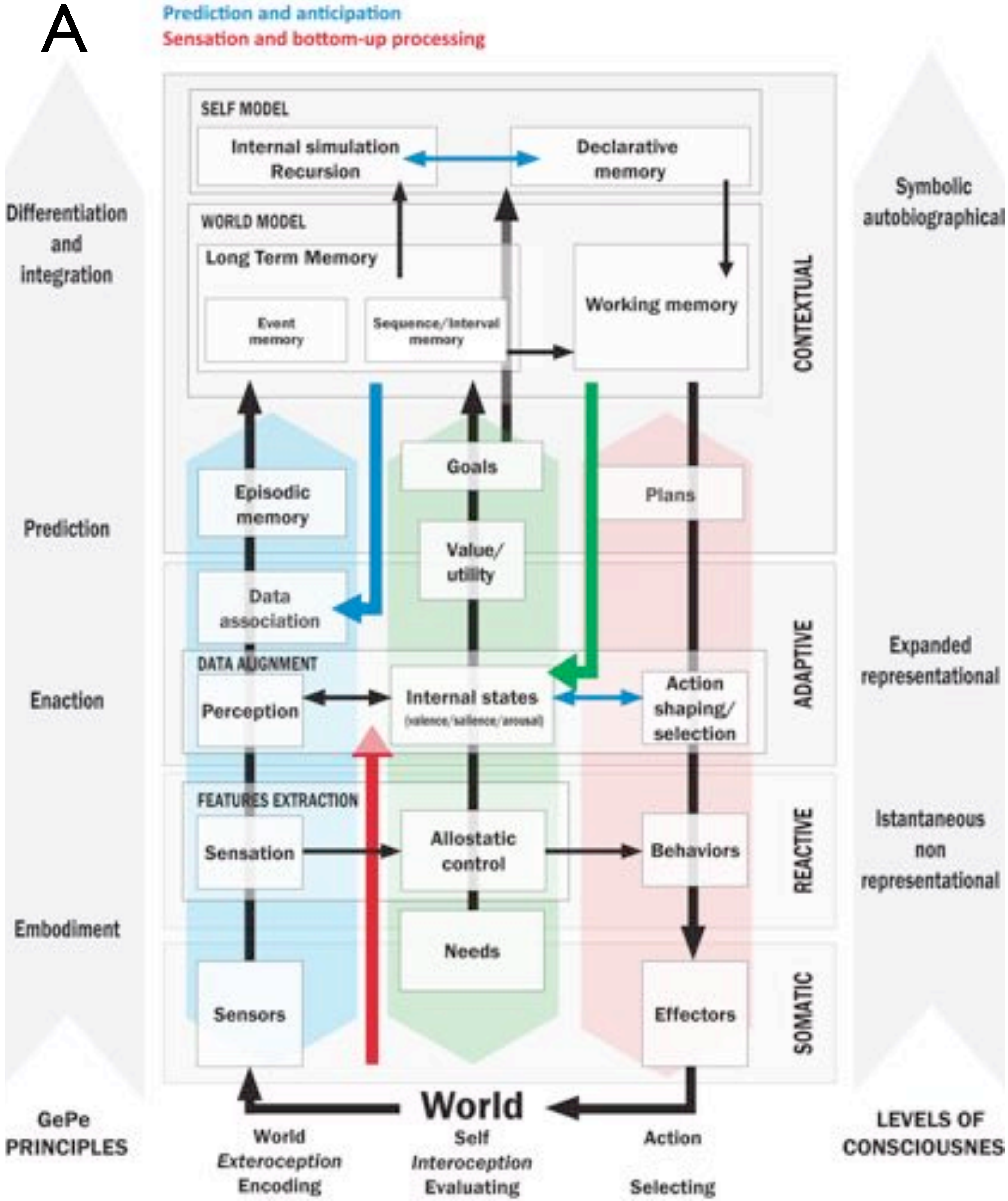
Distributed Adaptive Control



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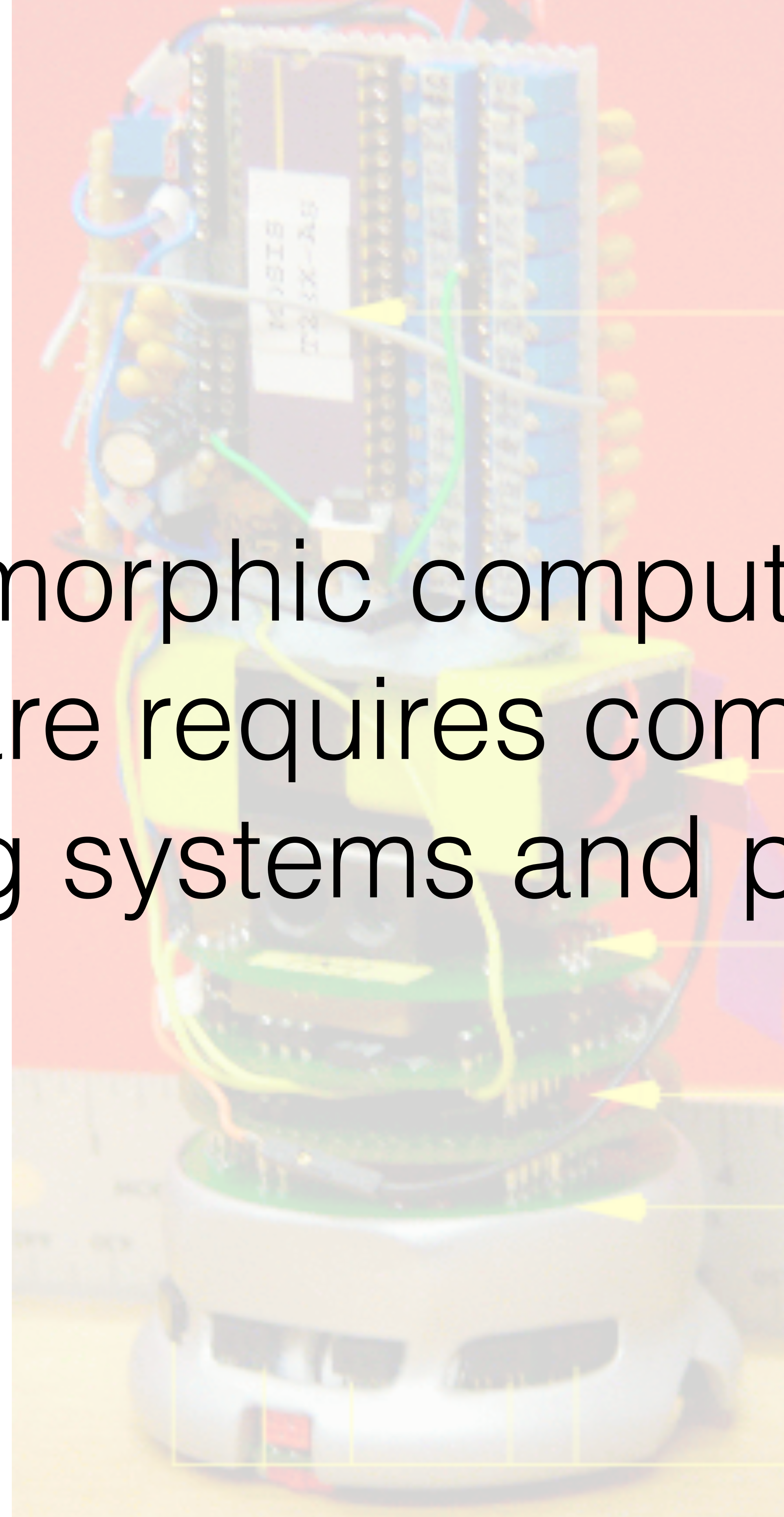

Neuromorphic computational hardware requires compatible operating systems and principles

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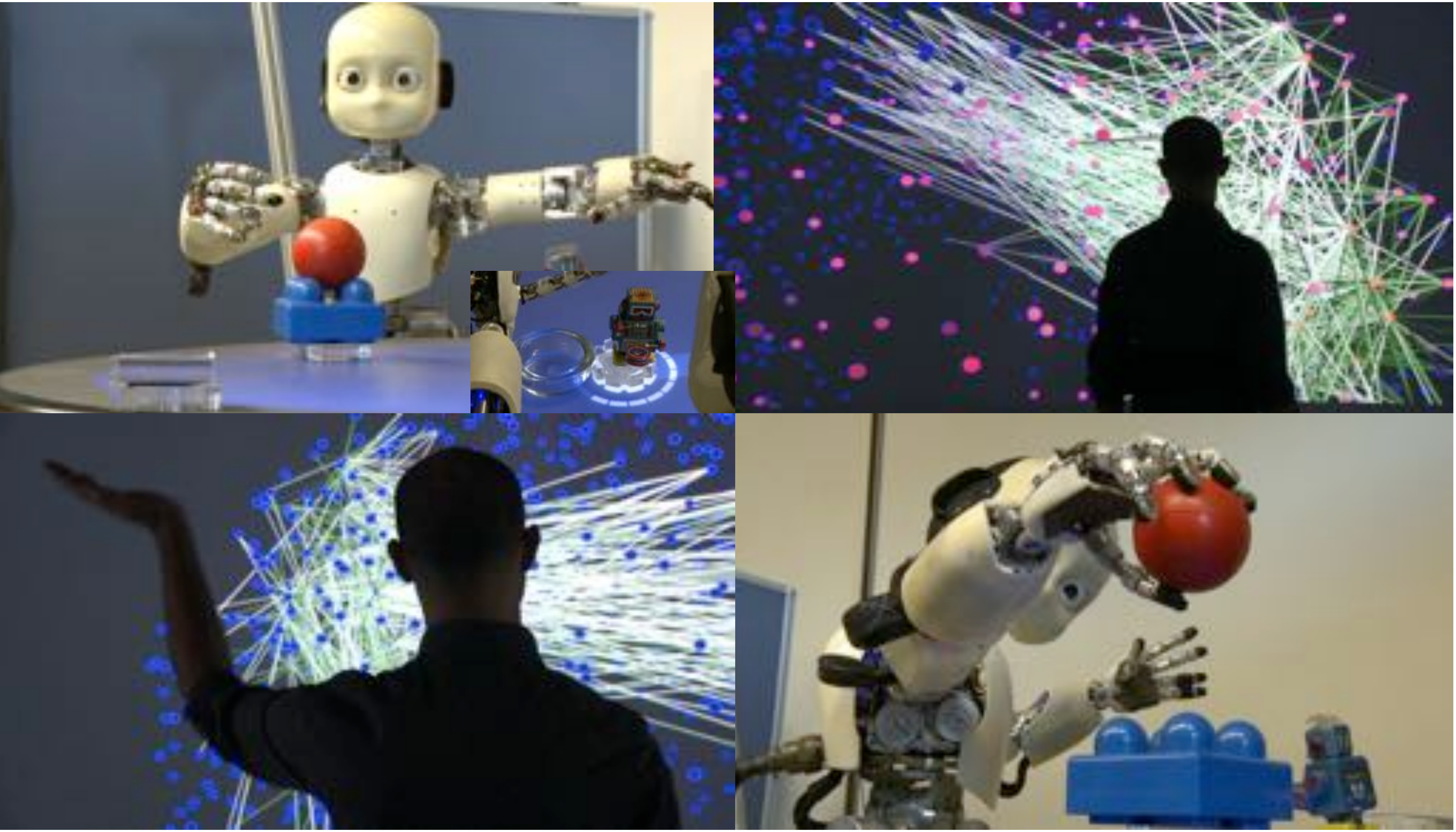
DAC-BRAINX3



Linking whole brain models with humanoid robots

Conclusions/Questions

- Robots need brains: We need cognitive architectures for robots (and beyond)
  - Real time control architectures require *neuromorphic* computational hardware
- Brain (models) need robots: We need system level theories of brains
  - *Neuromorphic* computational hardware requires compatible operating systems and principles
- Candidate Brain Based Cognitive Architecture:
  - DAC and brainx3.com

Requirements/SPECS for NMC

- Real-time control
- Advanced multi-modal sensing
- Heterogeneous parallel computation
- Large-scale modifiable connectivity
- High bandwidth communication
- RT/Online Accessibility, configurability and control
- Low power
- Environments and tools for interaction

Challenges, Opportunities

- The **AI revolution** is upon us, the non-EU companies are winning, WTA risk, EU cannot miss the boat
- Platforms/Technology should **serve questions** and solutions not vice versa, e.g FIWARE outcomes
- HBP platforms should be guided by clear and functional **objectives**
- Funding should facilitate **diversity** of science grounded approaches
- We must be **realistic** in defining relation with evolving state of the art in technology and societal needs
- EC must **capitalize** on expertise and effort of research community (CSN I & II experience)
- FET: **excellent** science needs excellent reviewing

The Rehabilitation Gaming System

Euronews, March 2016