Tufts
UNIVERSITY

COGNITIVE ARCHITECTURES

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VERSION 1.2

TODAY ON AI

- Cognitive architectures
- Cognitivist cognitive architectures
- Emergent cognitive architectures
- Choses of CAs
- Questions?

Ultimate AI goal

The ultimate goal of AI is to construct **generally intelligent systems** with intellectual capacities similar to humans

- The accepted paradigms for Generally Intelligent Systems:
  1. Multi-agent systems
  2. Blackboard systems

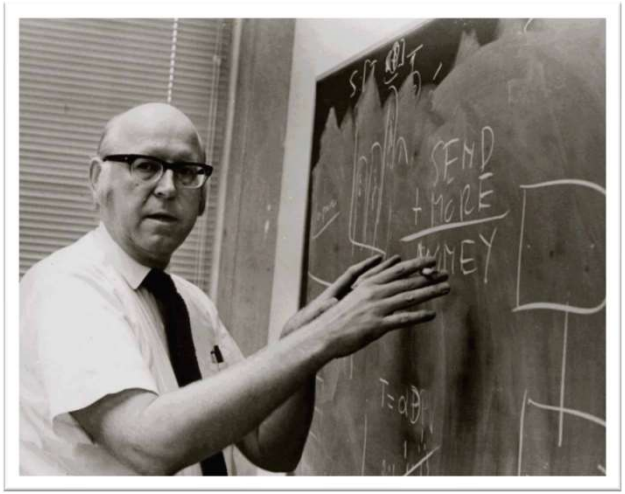
- AI is highly **fractured** in specific fields: **Computer Vision**, **Natural Language Processing**, **Planning**
- We tend to design algorithms for a **single domain**, and evaluated their effectiveness in that domain
- Good performance in these isolated systems **does not guarantee** generally intelligent systems

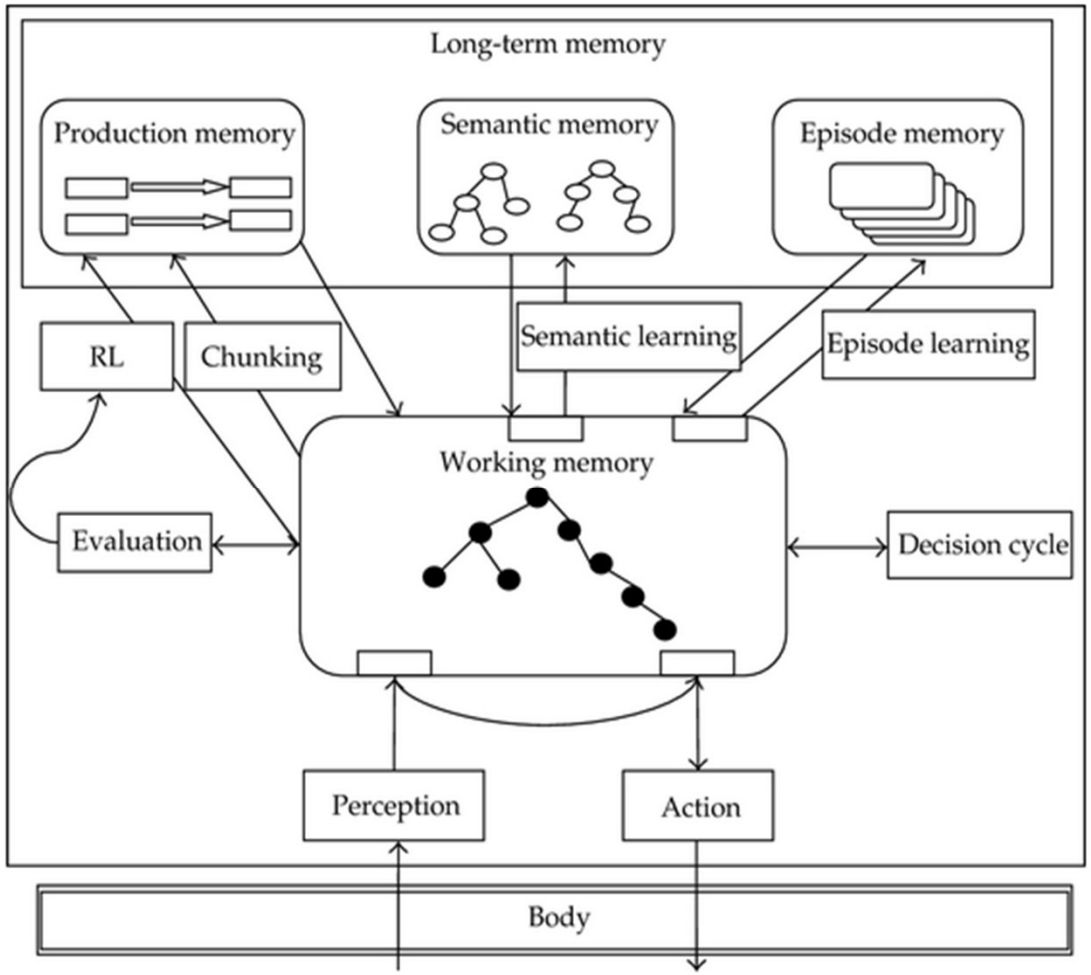
Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses

- **Allen Newell** (1973) critiqued cognitive psychologists who studied components of cognition (e.g., language, memory, attention) in isolation without considering their interaction

- His thesis was that Psychology is ready for **unified theories of cognition**

- In 1982, Newell was the first one to use the term **Cognitive Architecture**





SOAR

Laird, Newell, Rosenbloom (1987)

The goal of SOAR is to develop the fixed computational building blocks needed by a general intelligent agent.

We should develop general AI systems and evaluate them with based on their **generality and flexibility**, i.e., the breadth of domains they can handle

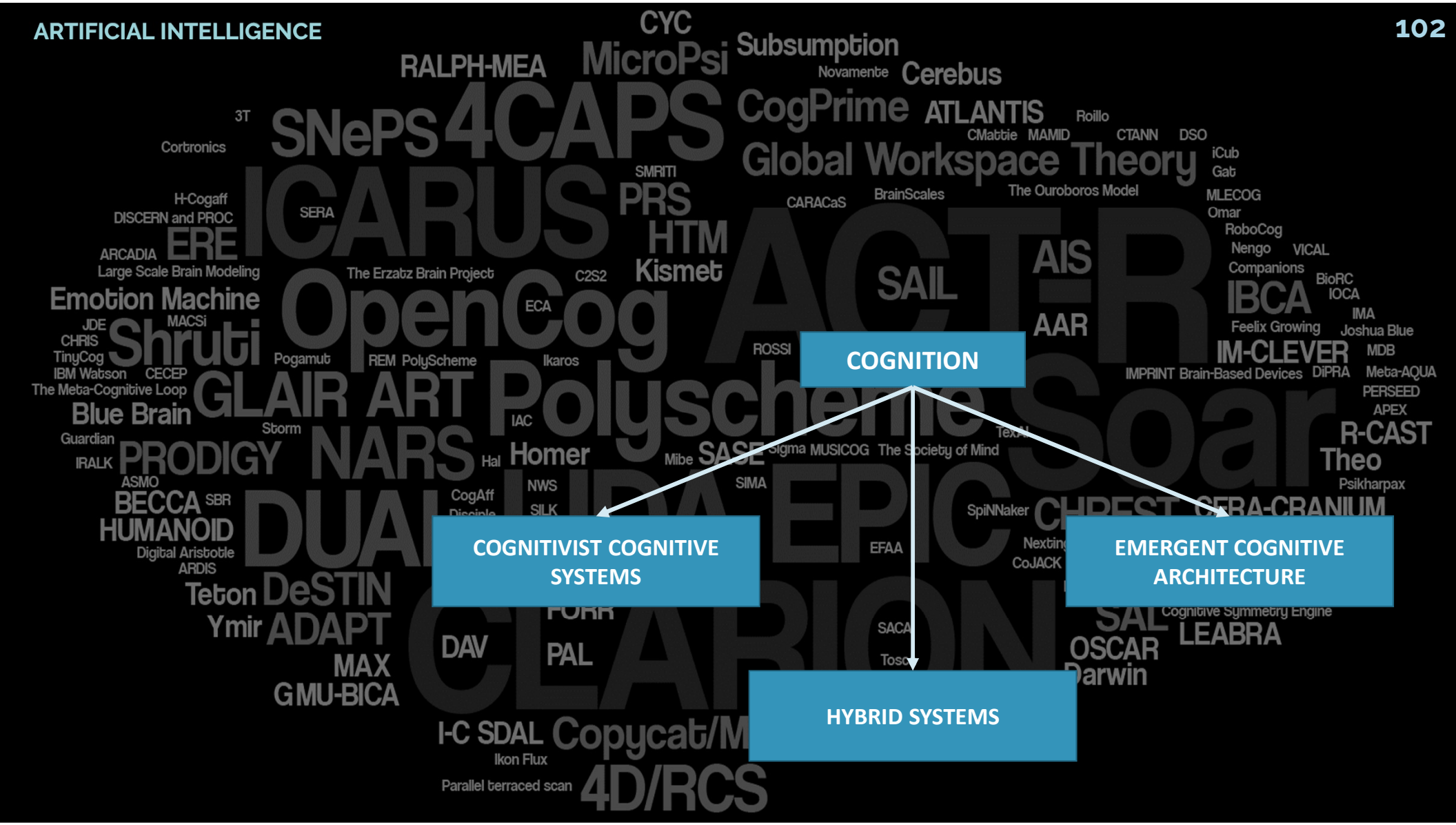
Cognitive architectures

SECTION 01

- Cognitive architectures go beyond by making **architectural commitments** base on cognitive theories

- A cognitive architecture is an **embodiment of a scientific hypothesis** about those aspects of human cognition that are:
  - **Constant over time**
  - **Independent of task**

- Overall structure and organization of a cognitive system:
  - **Essential Modules**
  - **Essential relations** between these modules
  - **Essential algorithmic and representational details** in each module


CYC
RALPH-MEA
MicroPsi
Subsumption
Novamente
Cerebus
3T
SNePS
4CAPS
CogPrime
ATLANTIS
Roillo
CMattie
MAMID
CTANN
DSO
Cortronics
Global Workspace Theory
iCub
Gat
SMRITI
ICARUS
PRS
CARACaS
BrainScales
The Ouroboros Model
MLECOG
Omar
H-Cogaff
DISCERN and PROC
SERA
HTM
RoboCog
ERE
Nengo
VICAL
ARCADIA
Large Scale Brain Modeling
The Erzatz Brain Project
C2S2
Kismet
AIS
Companions
ACT-R
SAIL
BioRC
IOCA
Emotion Machine
ECA
IBCA
IMA
JDE
MACSi
AAR
Feelix Growing
Joshua Blue
CHRIS
Shruti
OpenCog
ROSSI
IM-CLEVER
MDB
TinyCog
Pogamut
REM PolyScheme
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IMPRINT
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DiPRA
Meta-AQUA
IBM Watson
CECEP
GLAIR
ART
Polyscheme
Soar
The Meta-Cognitive Loop
PERSEED
Blue Brain
IAC
APEX
Storm
Guardian
NARS
Homer
Mibe
SASE
Sigma
MUSICOG
The Society of Mind
R-CAST
IRALK
PRODIGY
Hal
Theo
ASMO
SIMA
Psikharpax
NWS
CogAff
BECCA
SBR
SILK
DUAL
EPIC
SpiNNaker
CHREST
CERA-CRANIUM
HUMANOID
Digital Aristotle
EFAA
ARDIS
Nextin
CoJACK
Teton
DeSTIN
Cognitive Symmetry Engine
Ymir
ADAPT
SACA
LEABRA
CLARION
DAV
PAL
OSCAR
MAX
Darwin
GMU-BICA
I-C SDAL
Copycat/M
Ikon Flux
Parallel terraced scan
4D/RCS
COGNITION
COGNITIVIST COGNITIVE SYSTEMS
EMERGENT COGNITIVE ARCHITECTURE
HYBRID SYSTEMS

Cognitivist cognitive architectures

SECTION 02

- How are the agent's **beliefs**, **goals**, and **knowledge** stored and accessed in **short-term memory** and **long-term memory**?
- How are such memories **structured**?
- What **process** make use of these structures to make decisions and solve problems?

Cognitivist cognitive architectures try to answer questions like:

- What process adapt these structures to effect **learning**?
- How is **attention** directed, and what is its effect?
- How can we, as humans, actually go about **encoding knowledge and processes** (i.e., program) in a way that supports these commitments?

Emergent cognitive architectures

SECTION 03

Emergent approaches focus on development – from a primitive state – to fully cognitive state, over the system's lifetime

- The cognitive architecture is the system's **phylogenetic configuration** – the basis for **ontogenesis**: growth and development
  - **Innate skills**
  - **Core knowledge** (initial skills)

- A structure in which to embed mechanisms for:
  - **Perception**
  - **Action**
  - **Adaptation**
  - **Anticipation**
  - **Motivation**

- How does the agent's **physical morphology** affect development?

Children go through **four distinct stages** of cognitive development

Focuses on active **assimilation or accommodation** of new information

JEAN PIAGET
1896 - 1980

LEV VYGOTSKY
1896 - 1934

Cognitive development is **continuous**

Focuses on internalization of **interactions and dialogues**

1. **Sensorimotor stage** (0 – 2 years): the infants constructs an understanding of the world by coordinating sensory experiences with physical actions

2. **Preoperational stage** (2 – 7 years): the child beings to represent the world with words and images. These words and image reflect increased symbolic thinking and go beyond the connection of sensory information and physical action

3. **Concrete operational stage** (7 – 11 years): The child can now reason logically about concrete events and classify objects into different sets

4. **Formal operational stage** (11 – adulthood): The adolescent reasons in more abstract, idealistic, and logical ways

Choices of cognitive architectures

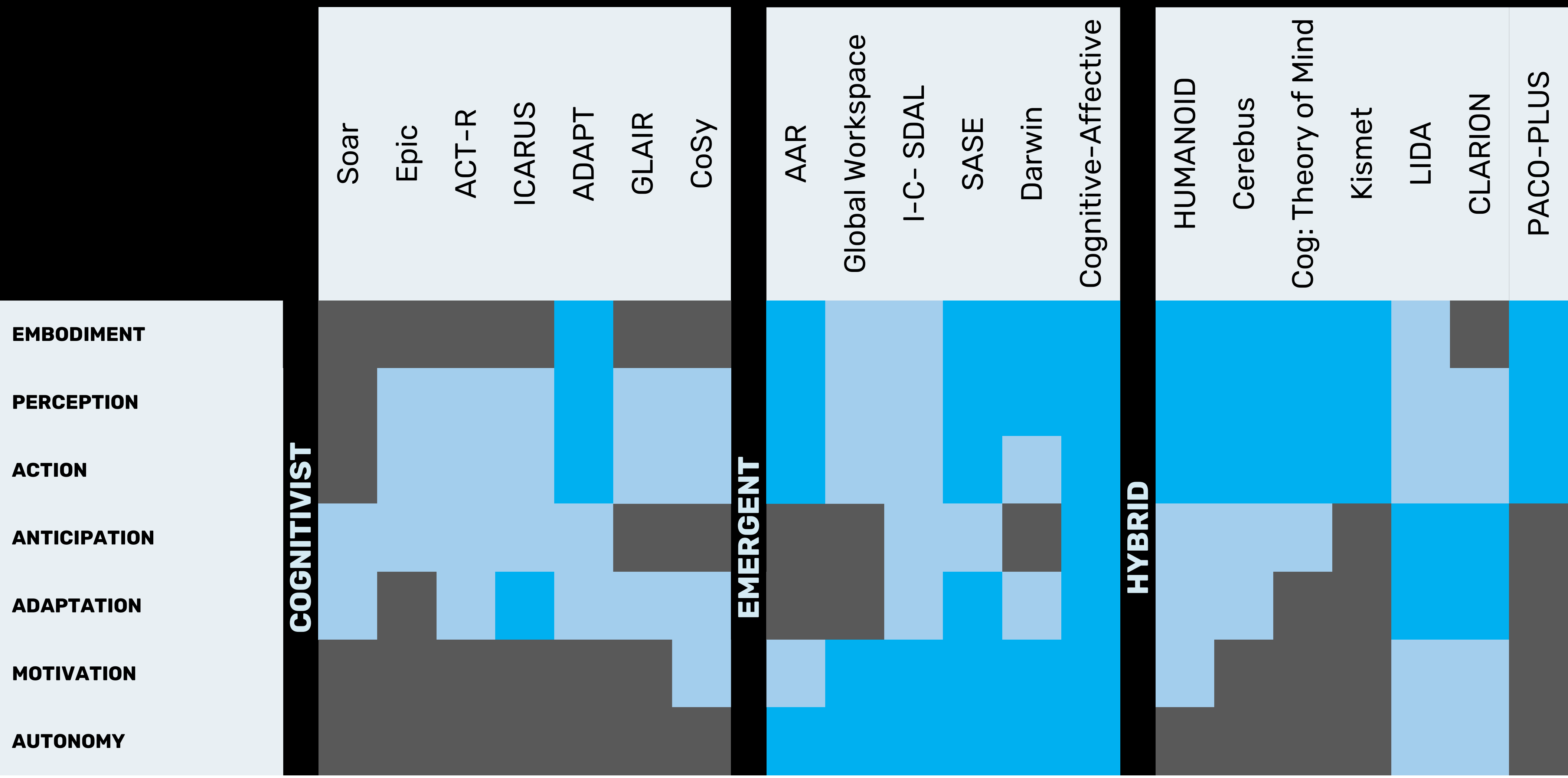
SECTION 04

- Is the architecture **ecologically realistic**?
  - Can it perform everyday activities?
  - Can it deal with simultaneous, conflicting goals?
  - Does it take embodiment into account?
- Is the architecture **evolutionarily realistic**?
  - Can it be reduced to a plausible model of animal cognition?
- Is the architecture **cognitively realistic**?
  - Does it capture the essential characteristics of behavior and cognition, based on our knowledge of psychology, philosophy, and neuroscience?
- Is it **methodologically general**?
  - A cognitive architecture shouldn't commit to specific methodologies unless there's a good reason for it, or future research could be overly constrained.

COGNITIVIST COGNITIVE ARCHITECTURES	EMERGENT COGNITIVE ARCHITECTURES
EMBODIMENT	
Cognition is independent of the physical platform in which it is implemented	Intrinsically embodied, the physical instantiation plays a direct constitutive role in the cognitive process
PERCEPTION	
Perception provides an interface between the external world and the symbolic representation of that world	Perception is a change in system state in response to environmental perturbations in order to maintain stability
ACTION	
Actions are causal consequences of symbolic processing of internal representations	Actions are perturbations of the environment by the system
ANTICIPATION	
Anticipation typically takes the form of planning using some form of procedural or probabilistic	Anticipation requires the system to visit a number of states in its self-constructed perception-action state space without committing to the associated actions

COGNITIVIST COGNITIVE ARCHITECTURES	EMERGENT COGNITIVE ARCHITECTURES
ADAPTATION	
Adaptation usually implies the acquisition of new knowledge	Entails a structural alteration or reorganization to effect a new set of dynamics
MOTIVATION	
Impinge on perception, action and adaption to resolve an impasse	Enlarge the space of interaction
AUTONOMY	
Is not necessarily implied	Autonomy is crucial since cognition is the process whereby an autonomous system becomes viable and effective

COGNITIVIST COGNITIVE ARCHITECTURES	HYBRID SYSTEMS	EMERGENT COGNITIVE ARCHITECTURES
• **Soar** [Newell et al. 1987] • **EPIC** [Kieras & Meyer 1997] • **ICARUS** [Langley 05, Langley 2006] • **GLAIR** [Shapiro & Bona 2009] • **CoSy** [Hawes & Wyatt 2008]	• **CLARION** [Sun 2007] • **ACT-R** [Anderson et al. 2004] • **ACT-R/E** [Trafton et al. 2013] • **KHR** [Burghart et al. 2005] • **LIDA** [Franklin et al. 2007, Baars & Franklin 2009] • **PACO-PLUS** [Kraft et al. 2008]	• **iCub** [Vernon et al. 2010] • **Global Workspace** [Shanahan 2006] • **SASE** [Weng 2004] • **Darwin** [Krichmar et al. 2005] • **Cognitive Affective** [Morse et al 2008]


COGNITIVIST
Soar
Epic
ACT-R
ICARUS
ADAPT
GLAIR
CoSy
EMERGENT
AAR
Global Workspace
I-C- SDAL
SASE
Darwin
Cognitive-Affective
HYBRID
HUMANOID
Cerebus
Cog: Theory of Mind
Kismet
LIDA
CLARION
PACO-PLUS
EMBODIMENT
PERCEPTION
ACTION
ANTICIPATION
ADAPTATION
MOTIVATION
AUTONOMY

There are many aspects and open questions regarding cognition in humans:

Attention
Memory
Problem solving
Decision making
Learning
Concept formation
Embodiment
Reasoning
Prospection
Motivation
Planning
Language
Representation

QUESTIONS ?