The Situation Model Framework:
Implications for the Design of Cognitive Architectures

Cognitive Behavior of Humans, Animals, and Machines: Situation Model Perspectives

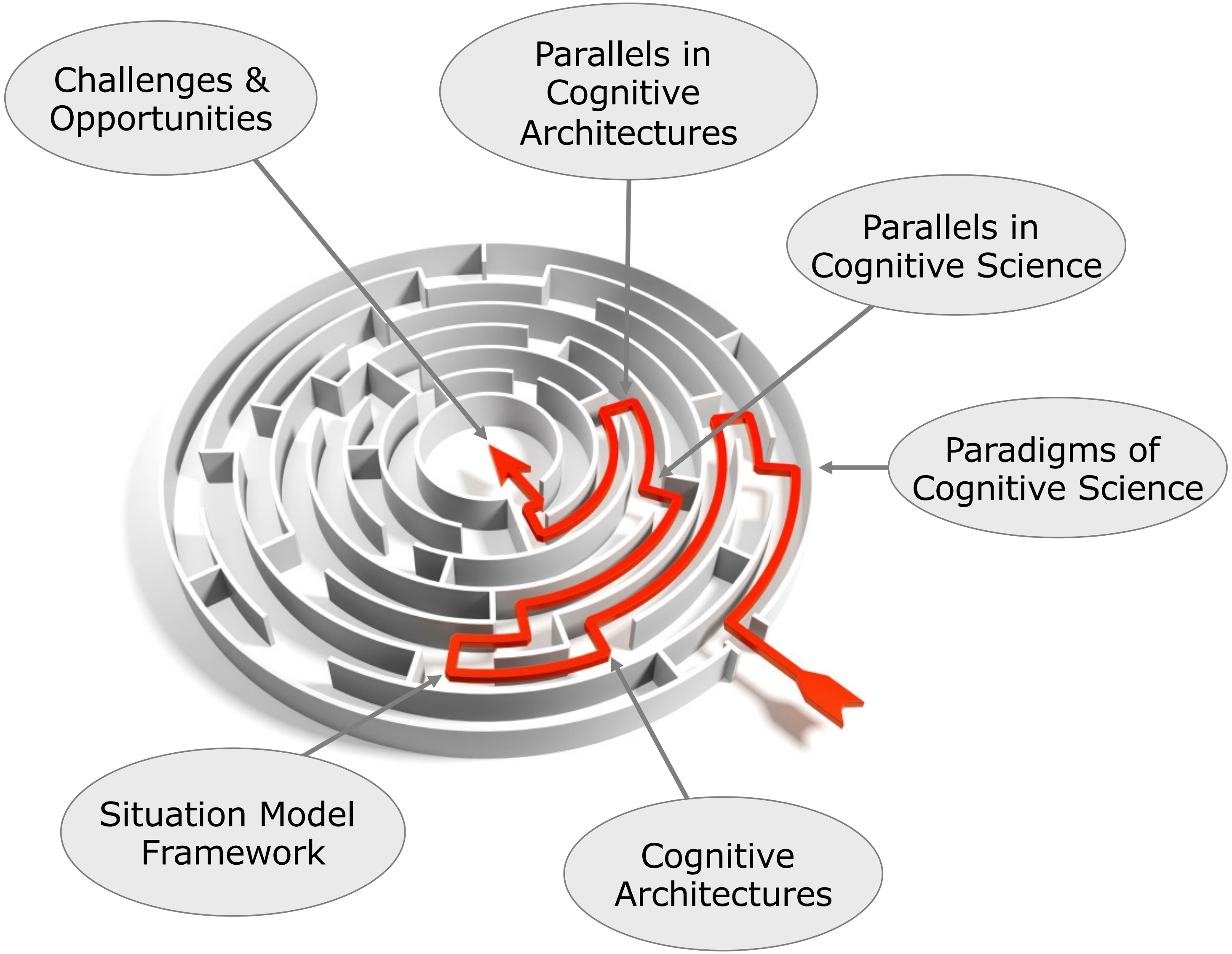
ZiF Zentrum für interdisziplinäre Forschung
Center for Interdisciplinary Research

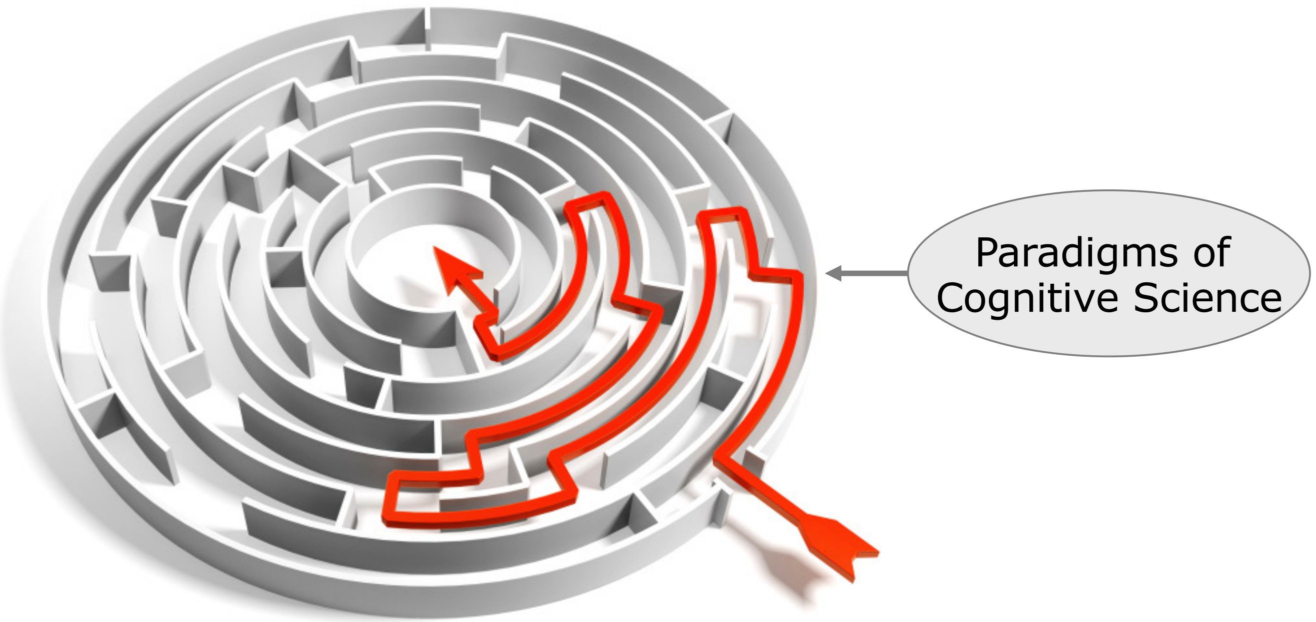
2 July 2020

David Vernon
Carnegie Mellon University Africa

www.vernon.eu

Thanks to the ZiF

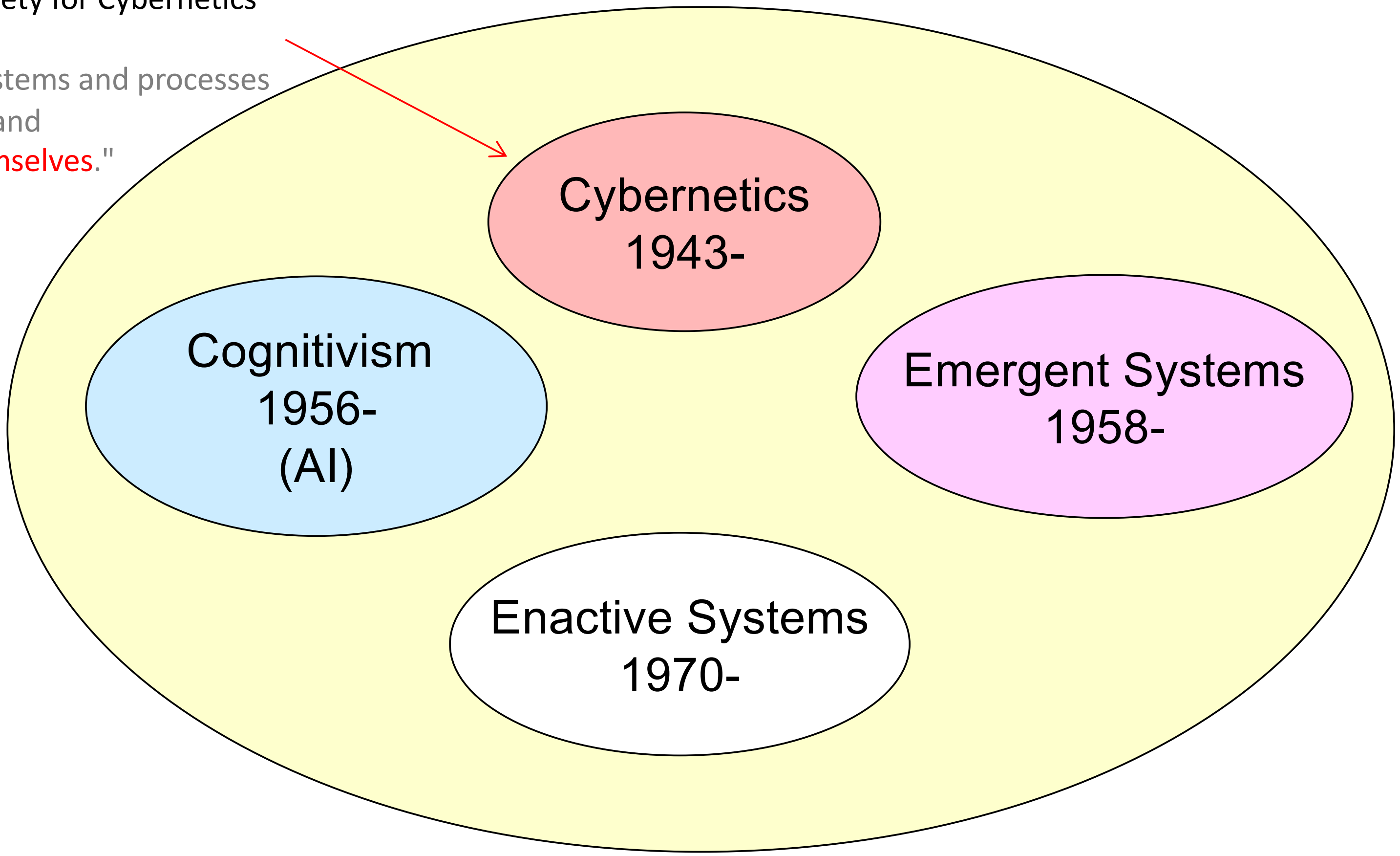

Challenges & Opportunities
Parallels in Cognitive Architectures
Parallels in Cognitive Science
Paradigms of Cognitive Science
Situation Model Framework
Cognitive Architectures


Paradigms of
Cognitive Science

Cognitive Science

Louis Kauffman
President of the American Society for Cybernetics

"Cybernetics is the study of systems and processes that interact with themselves and produce themselves from themselves."

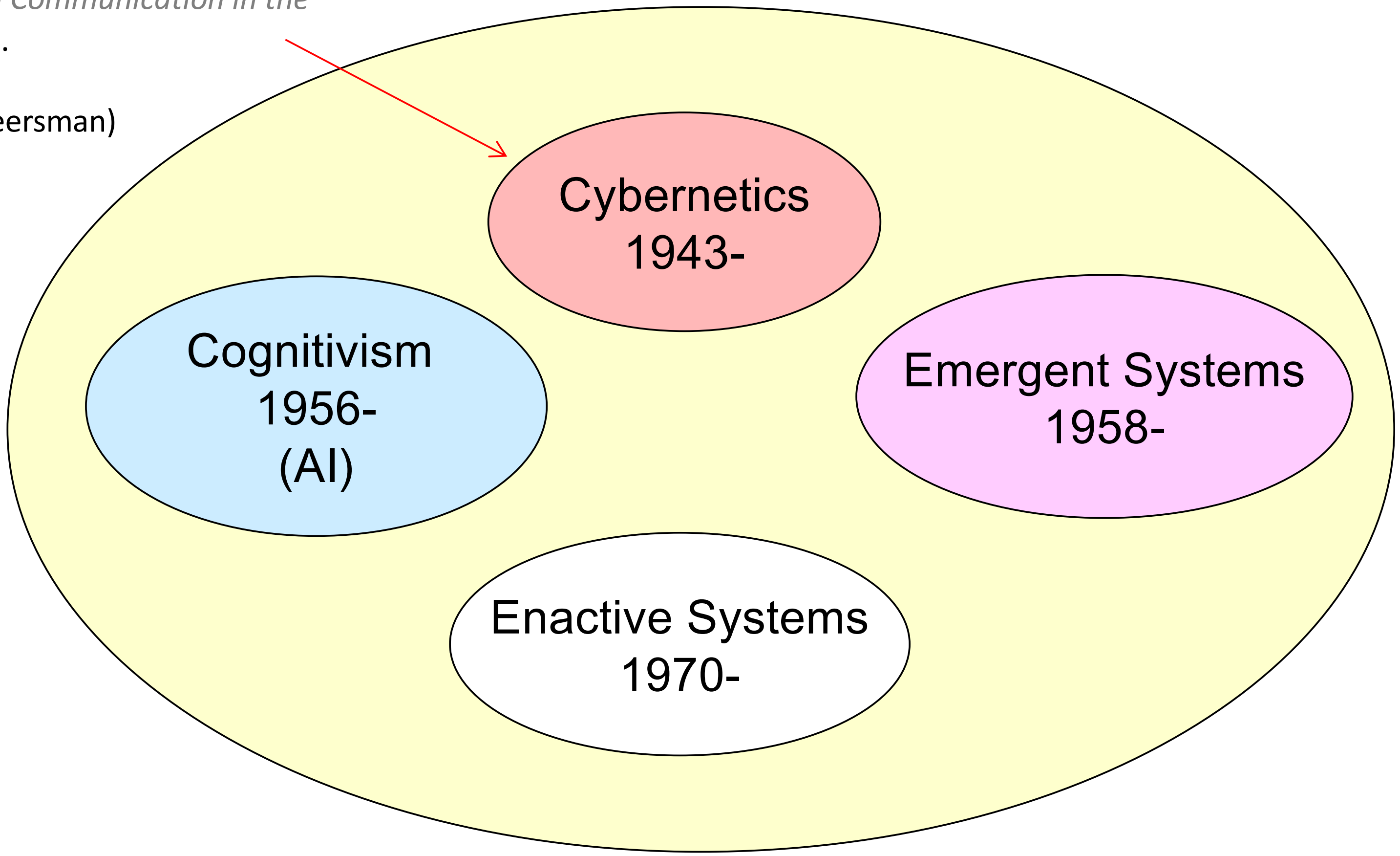


F. J. Varela. Whence perceptual meaning? A cartography of current ideas. In F. J. Varela and J.-P. Dupuy, editors, Understanding Origins – Contemporary Views on the Origin of Life, Mind and Society, Boston Studies in the Philosophy of Science, pages 235–263, Dordrecht, 1992. Kluwer Academic Publishers.

Cognitive Science

N. Wiener
Cybernetics: or the Control and Communication in the Animal and the Machine, 1948.

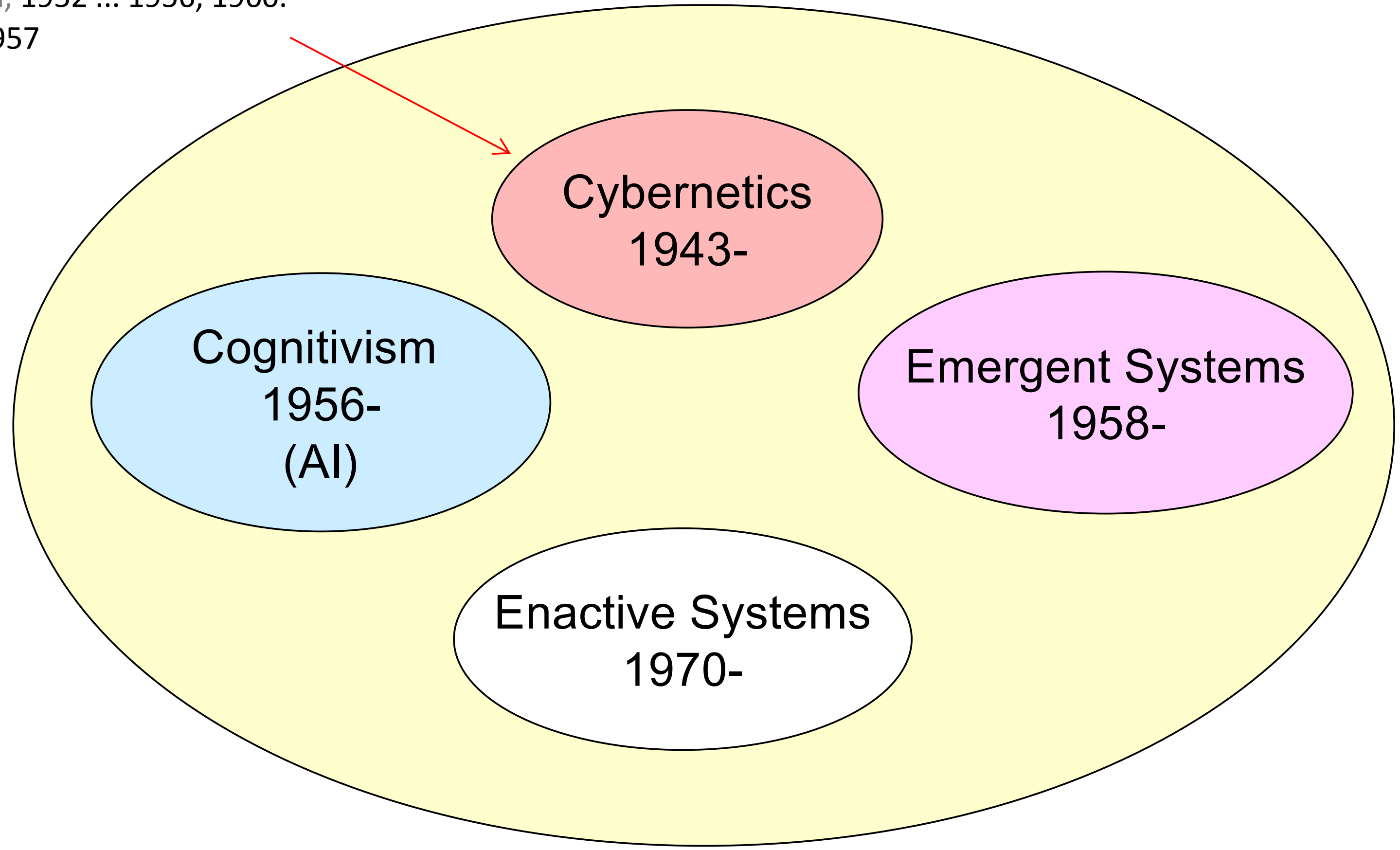
(*κυβερνητης* or kybernetes: steersman)



F. J. Varela. Whence perceptual meaning? A cartography of current ideas. In F. J. Varela and J.-P. Dupuy, editors, Understanding Origins – Contemporary Views on the Origin of Life, Mind and Society, Boston Studies in the Philosophy of Science, pages 235–263, Dordrecht, 1992. Kluwer Academic Publishers.

Cognitive Science

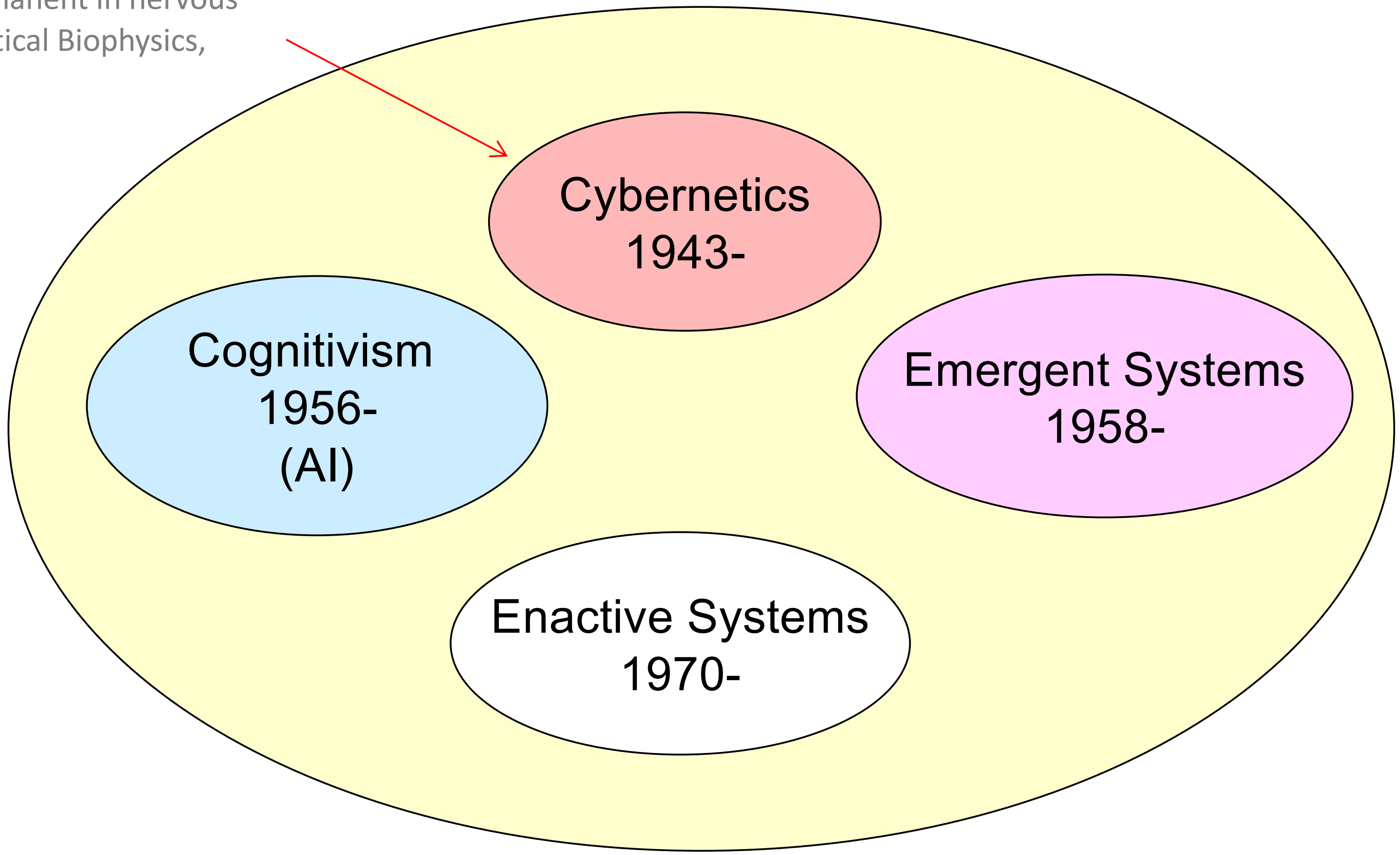
W. R. Ashby.
Design for a Brain, first edition, 1952 ... 1956, 1960.
Introduction to Cybernetics, 1957



F. J. Varela. Whence perceptual meaning? A cartography of current ideas. In F. J. Varela and J.-P. Dupuy, editors, Understanding Origins – Contemporary Views on the Origin of Life, Mind and Society, Boston Studies in the Philosophy of Science, pages 235–263, Dordrecht, 1992. Kluwer Academic Publishers.

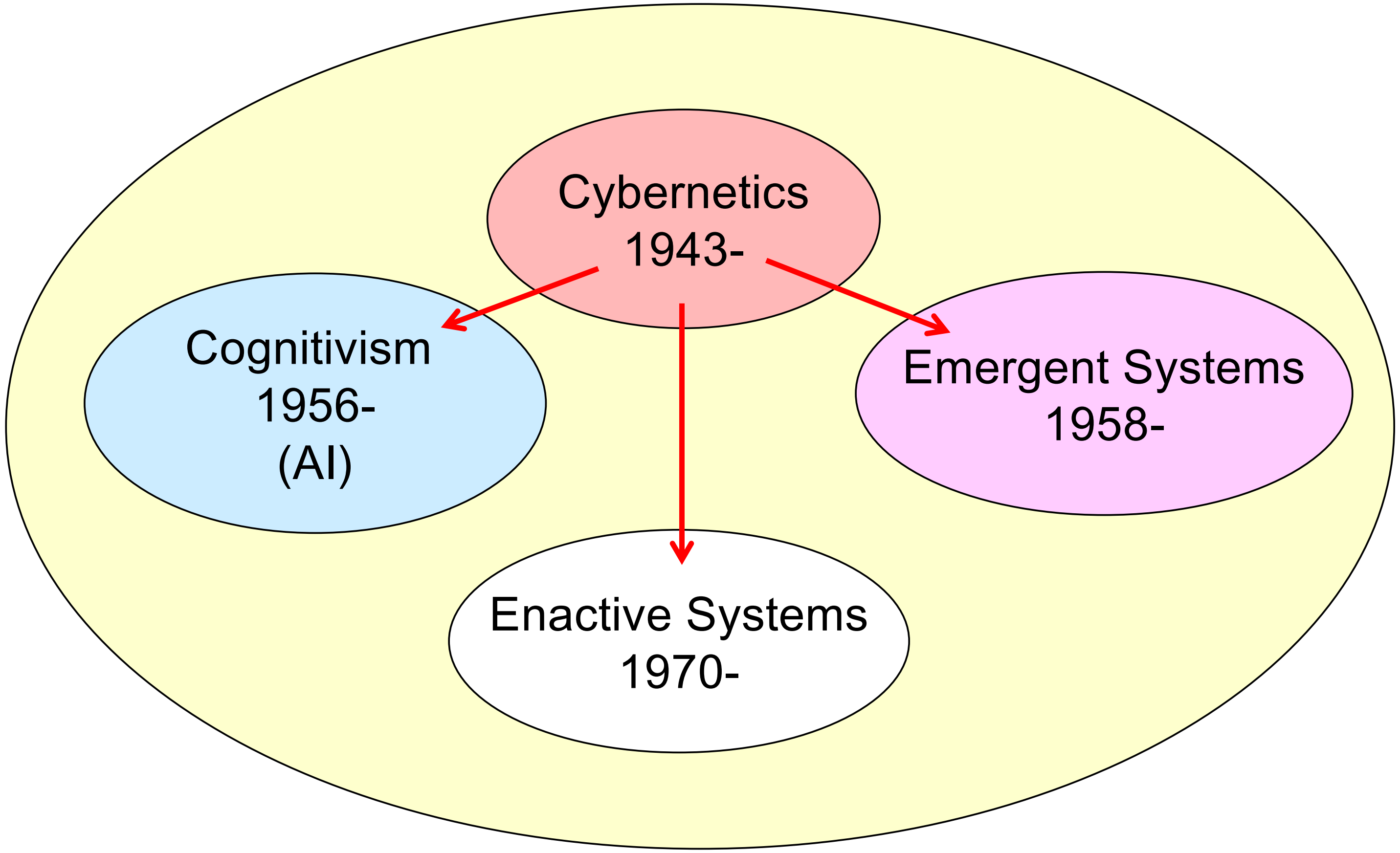
Cognitive Science

W. S. McCulloch and W. Pitts.
"A logical calculus of ideas immanent in nervous activity", Bulletin of Mathematical Biophysics, 5:115–133, 1943.

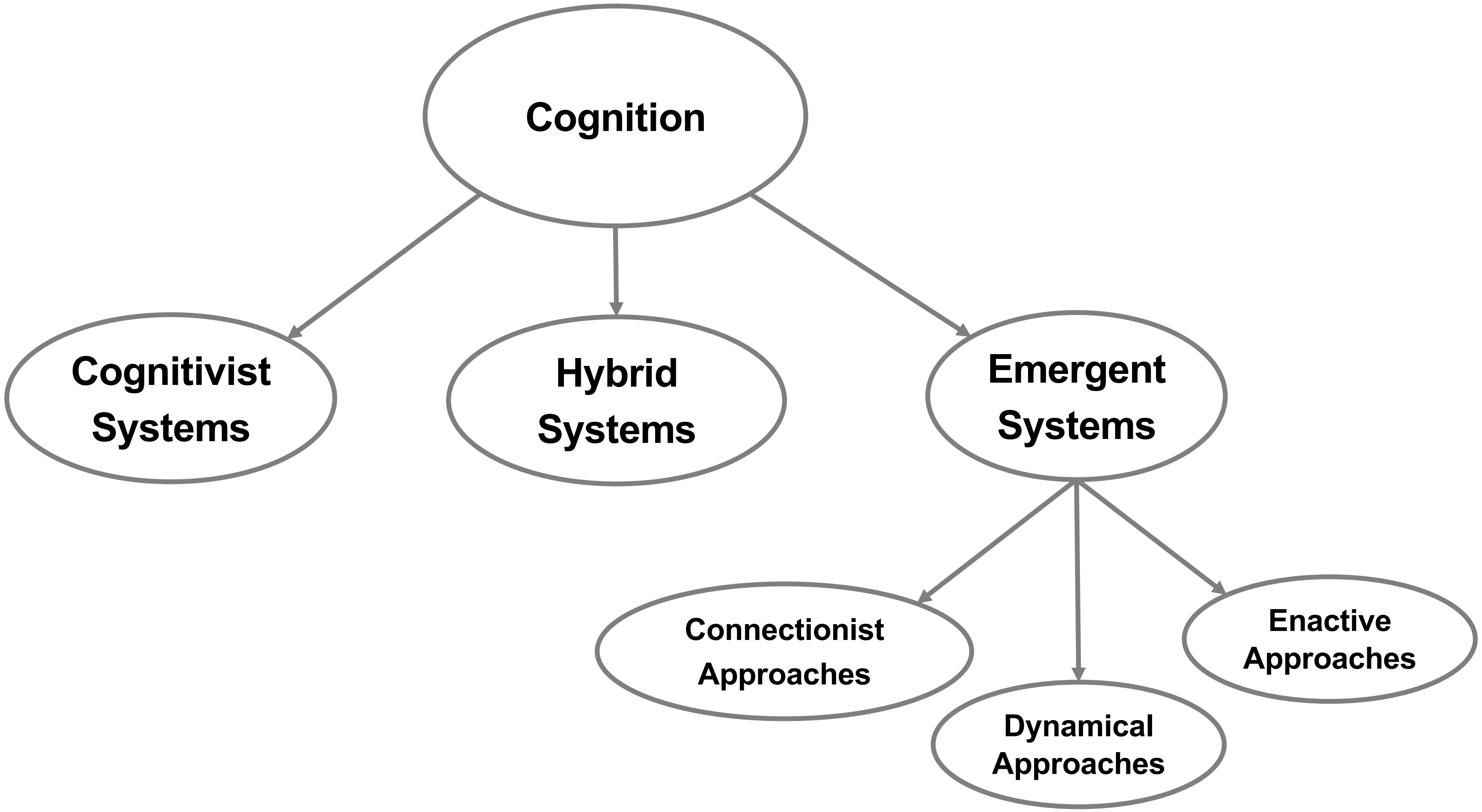


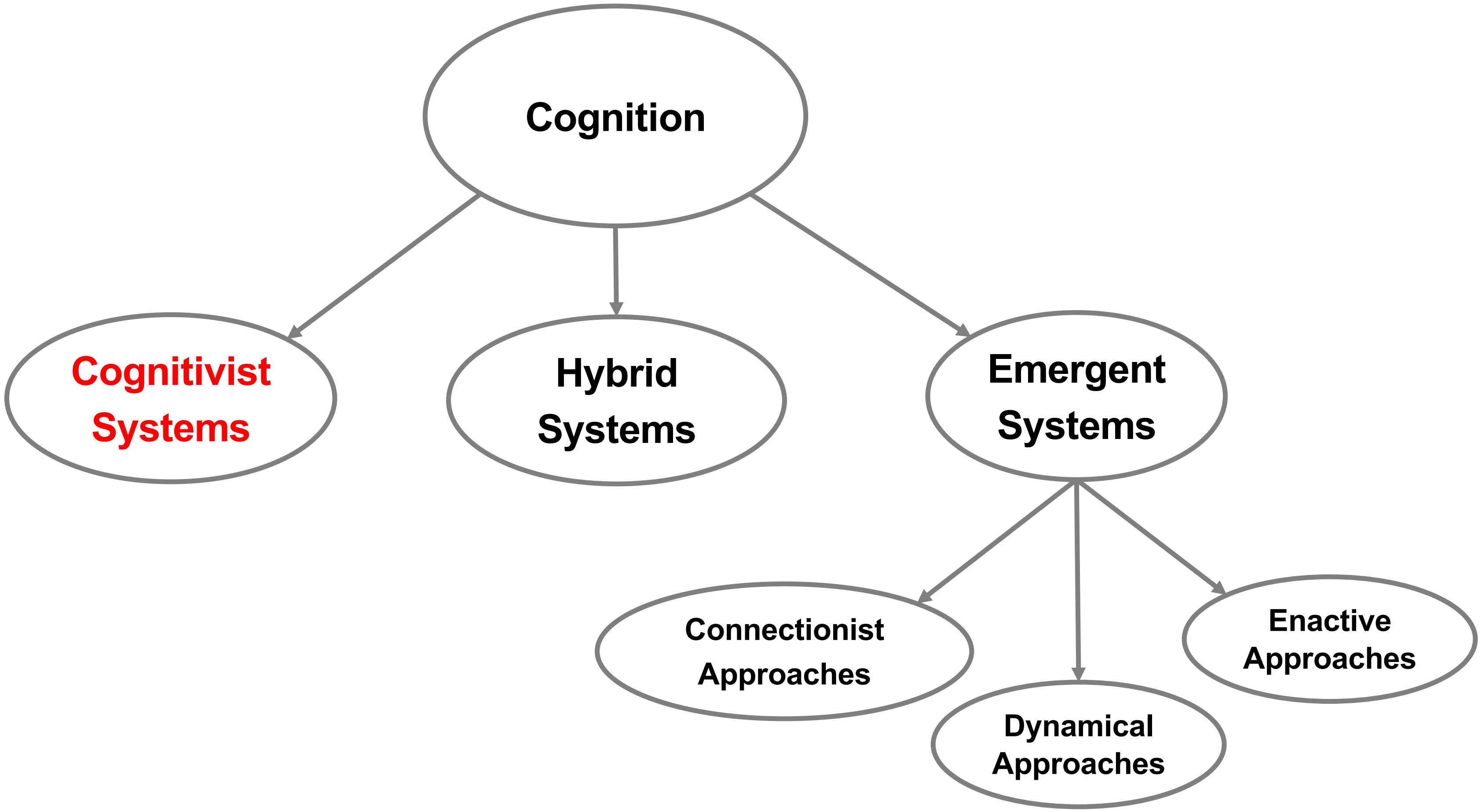
F. J. Varela. Whence perceptual meaning? A cartography of current ideas. In F. J. Varela and J.-P. Dupuy, editors, Understanding Origins – Contemporary Views on the Origin of Life, Mind and Society, Boston Studies in the Philosophy of Science, pages 235–263, Dordrecht, 1992. Kluwer Academic Publishers.

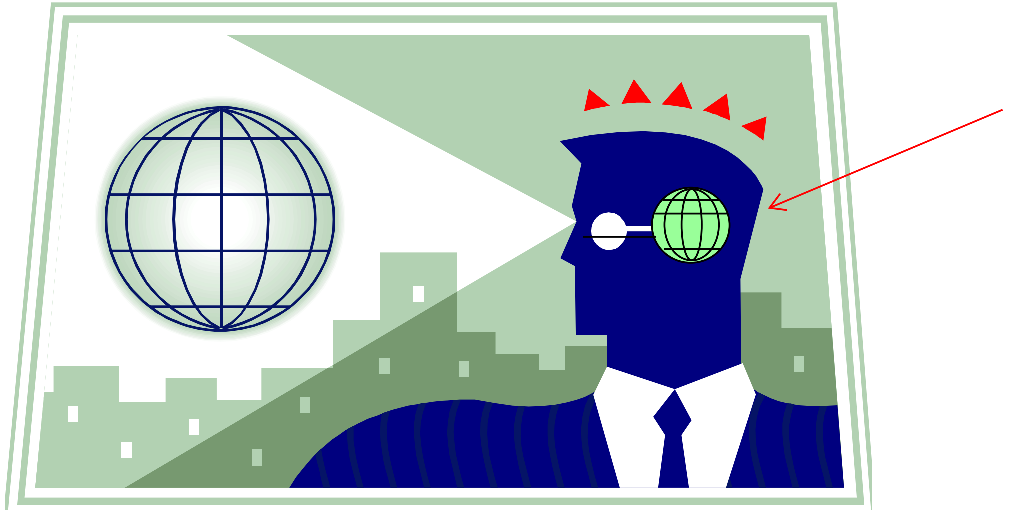
Cognitive Science



F. J. Varela. Whence perceptual meaning? A cartography of current ideas. In F. J. Varela and J.-P. Dupuy, editors, Understanding Origins – Contemporary Views on the Origin of Life, Mind and Society, Boston Studies in the Philosophy of Science, pages 235–263, Dordrecht, 1992. Kluwer Academic Publishers.


Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches


Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches



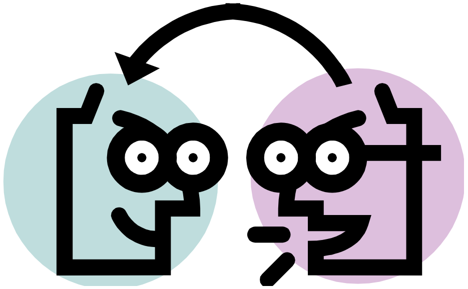
Explicit & symbolic

Representations denote external objects

Isomorphic

Absolute and accessible ontology

That is consistent with human expression



Explicit & symbolic

Representations denote external objects

Isomorphic

Absolute and accessible ontology

That is consistent with human expression

Robots That Use the Web as an Information Resource

By Moritz Tenorth, Ulrich Klank, Dejan Pangercic,and Michael Beetz

Web-Enabled Robots

Cognitivism & Artificial Intelligence

- Physical symbol system approach to AI
- Intelligence
  - Principle of rationality [Newell 82]

    'If an agent has knowledge that one of its actions will lead to one of its goals, then the agent will select that action'

  - Rational analysis [Anderson 89]

    'The cognitive system optimizes the adaptation of the behaviour of the organism'.

Cognitivism & Artificial Intelligence

Physical Symbol Systems

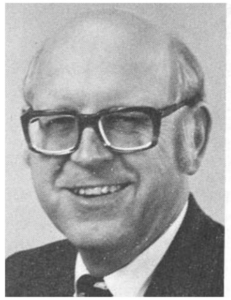
[Newell and Simon 1976]

The Physical Symbol System Hypothesis

A physical symbol system has the necessary and sufficient means of general intelligence

Computer Science as Empirical Inquiry: Symbols and Search

Allen Newell and Herbert A. Simon



Computer science is the study of the phenomena surrounding computers. The founders of this society understood this very well when they called themselves the Association for Computing Machinery. The machine—not just the hardware, but the programmed, living machine—is the organism we study.

This is the tenth Turing Lecture. The nine persons who preceded us on this platform have presented nine different views of computer science. For our organism, the machine, can be studied at many levels and from many sides. We are deeply honored to appear here today and to present yet another view, the one that has permeated the scientific work for which we have been

Key Words and Phrases: symbols, search, science, computer science, empirical, Turing, artificial intelligence, intelligence, list processing, cognition, heuristics, problem solving.

CR Categories: 1.0, 2.1, 3.3, 3.6, 5.7.

The authors' research over the years has been supported in part by the Advanced Research Projects Agency of the Department of Defense (monitored by the Air Force Office of Scientific Research) and in part by the National Institutes of Mental Health.

Authors' address: Carnegie-Mellon University, Pittsburgh.

113

Communications of the ACM

March 1976
Volume 19
Number 3

Cognitivism & Artificial Intelligence

Physical Symbol Systems

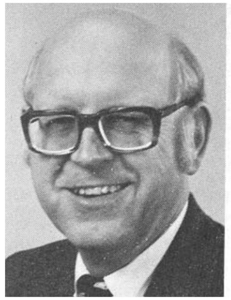
[Newell and Simon 1976]

The Heuristic Search Hypothesis

The task of intelligence is to avert the ever-present threat of the exponential explosion of search

Computer Science as Empirical Inquiry: Symbols and Search

Allen Newell and Herbert A. Simon



Computer science is the study of the phenomena surrounding computers. The founders of this society understood this very well when they called themselves the Association for Computing Machinery. The machine—not just the hardware, but the programmed, living machine—is the organism we study.

This is the tenth Turing Lecture. The nine persons who preceded us on this platform have presented nine different views of computer science. For our organism, the machine, can be studied at many levels and from many sides. We are deeply honored to appear here today and to present yet another view, the one that has permeated the scientific work for which we have been

Key Words and Phrases: symbols, search, science, computer science, empirical, Turing, artificial intelligence, intelligence, list processing, cognition, heuristics, problem solving.

CR Categories: 1.0, 2.1, 3.3, 3.6, 5.7.

The authors' research over the years has been supported in part by the Advanced Research Projects Agency of the Department of Defense (monitored by the Air Force Office of Scientific Research) and in part by the National Institutes of Mental Health.

Authors' address: Carnegie-Mellon University, Pittsburgh.

113

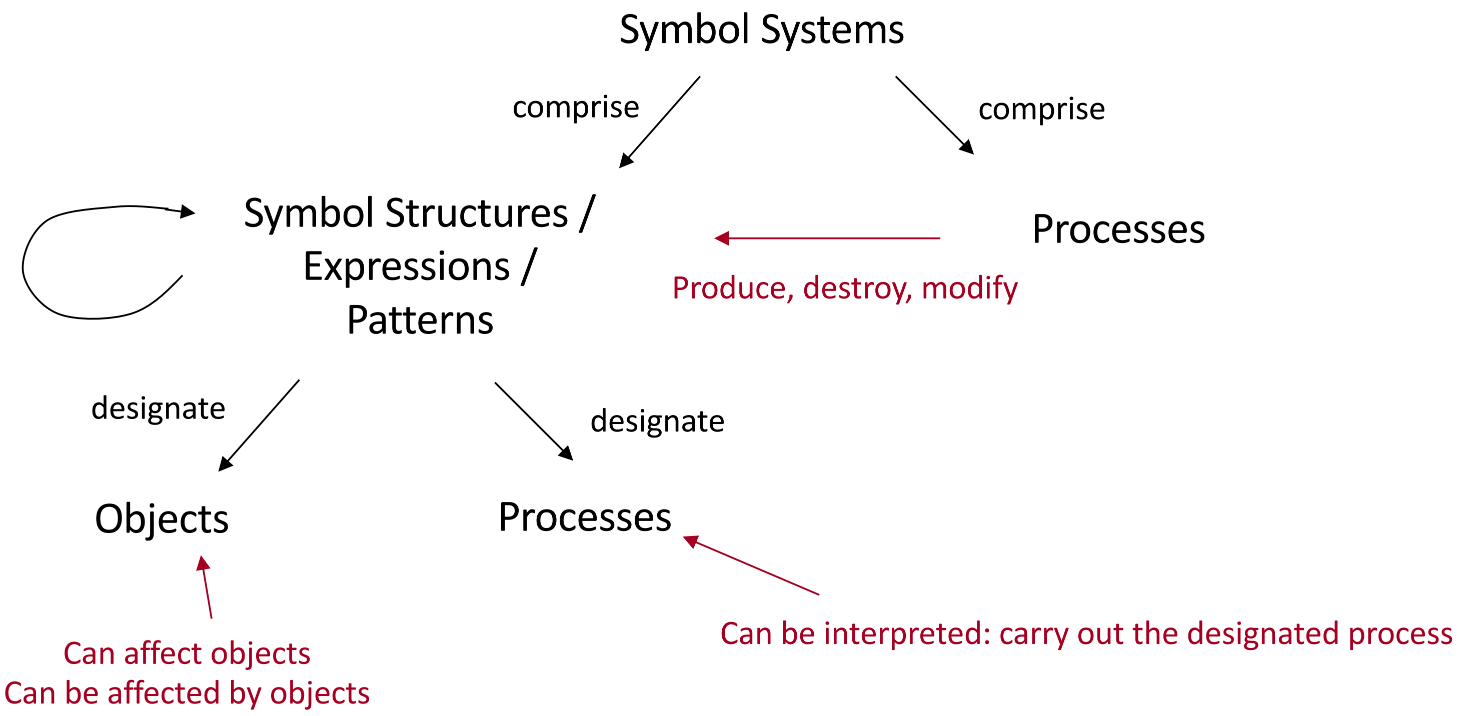
Communications of the ACM

March 1976 Volume 19 Number 3

Cognitivism & Artificial Intelligence

Physical Symbol Systems

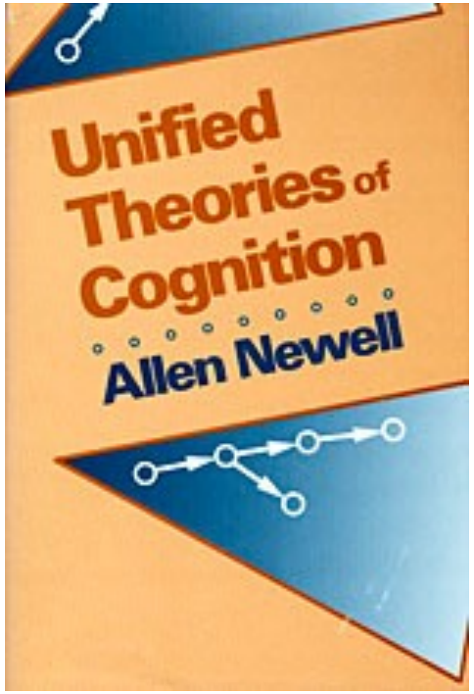
[Newell and Simon 1976]

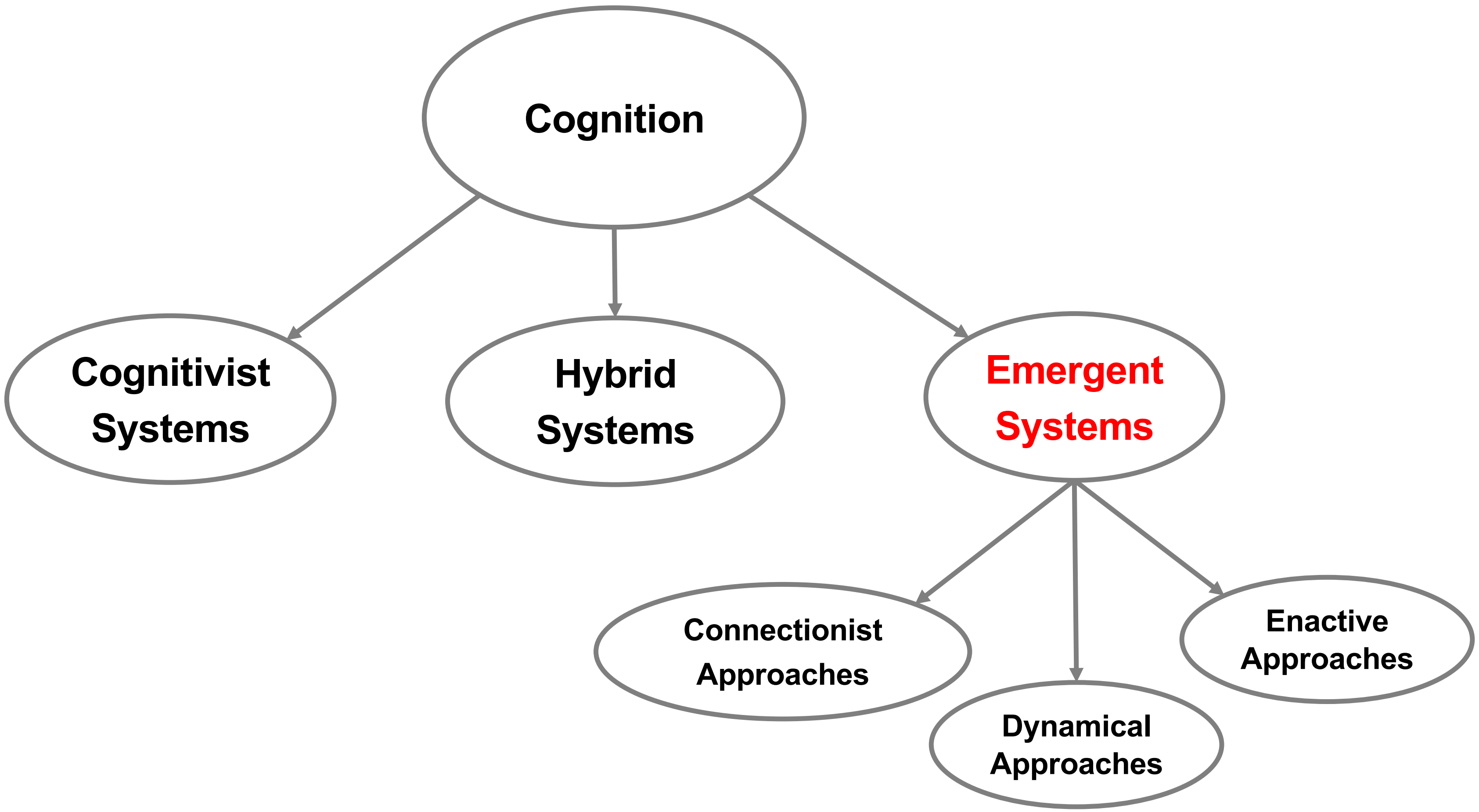


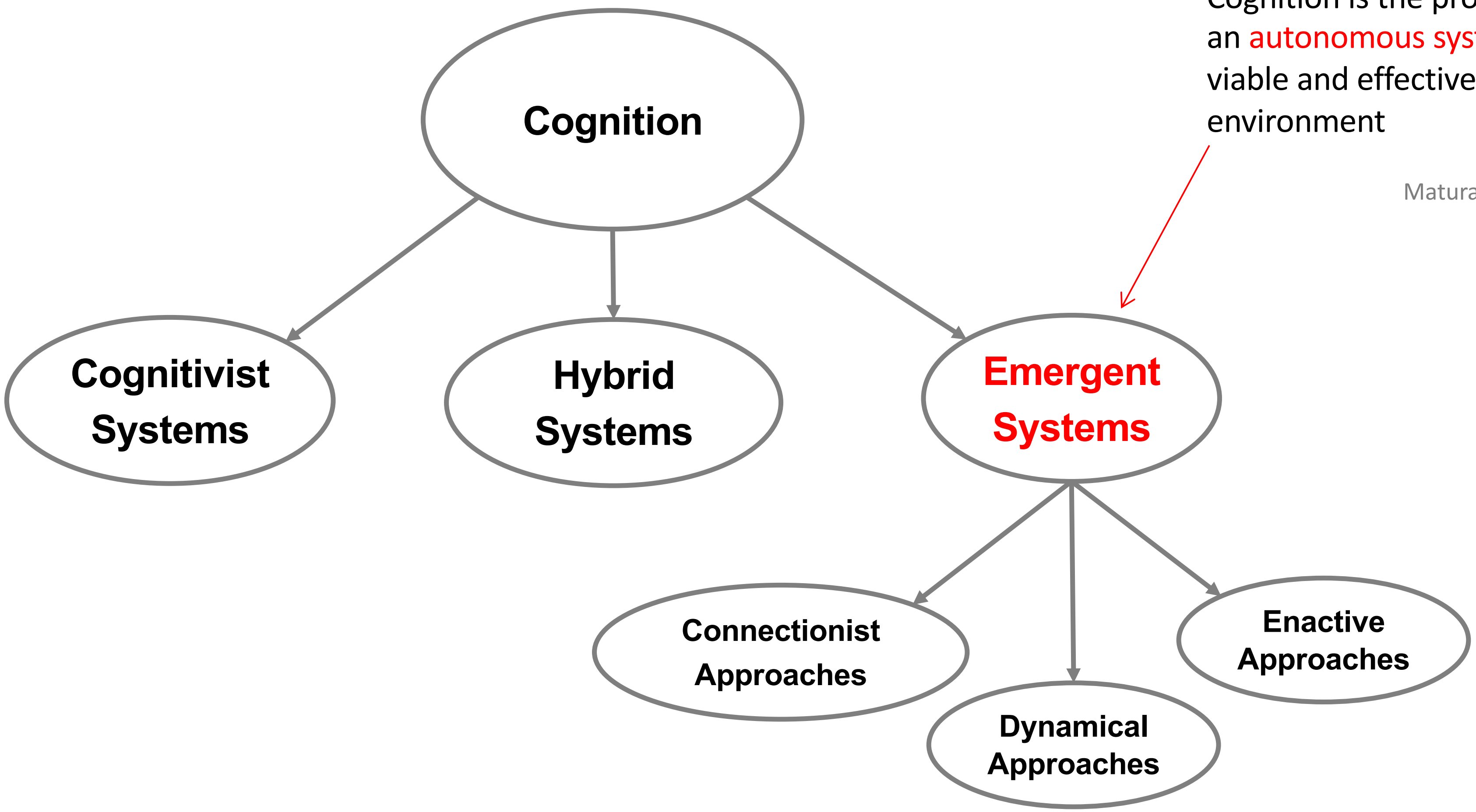
Cognitivism & Artificial Intelligence

Unified Theories of Cognition

- Attempts to explain all the mechanisms of all problems in its domain
- Applies to both natural and artificial cognition




Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches

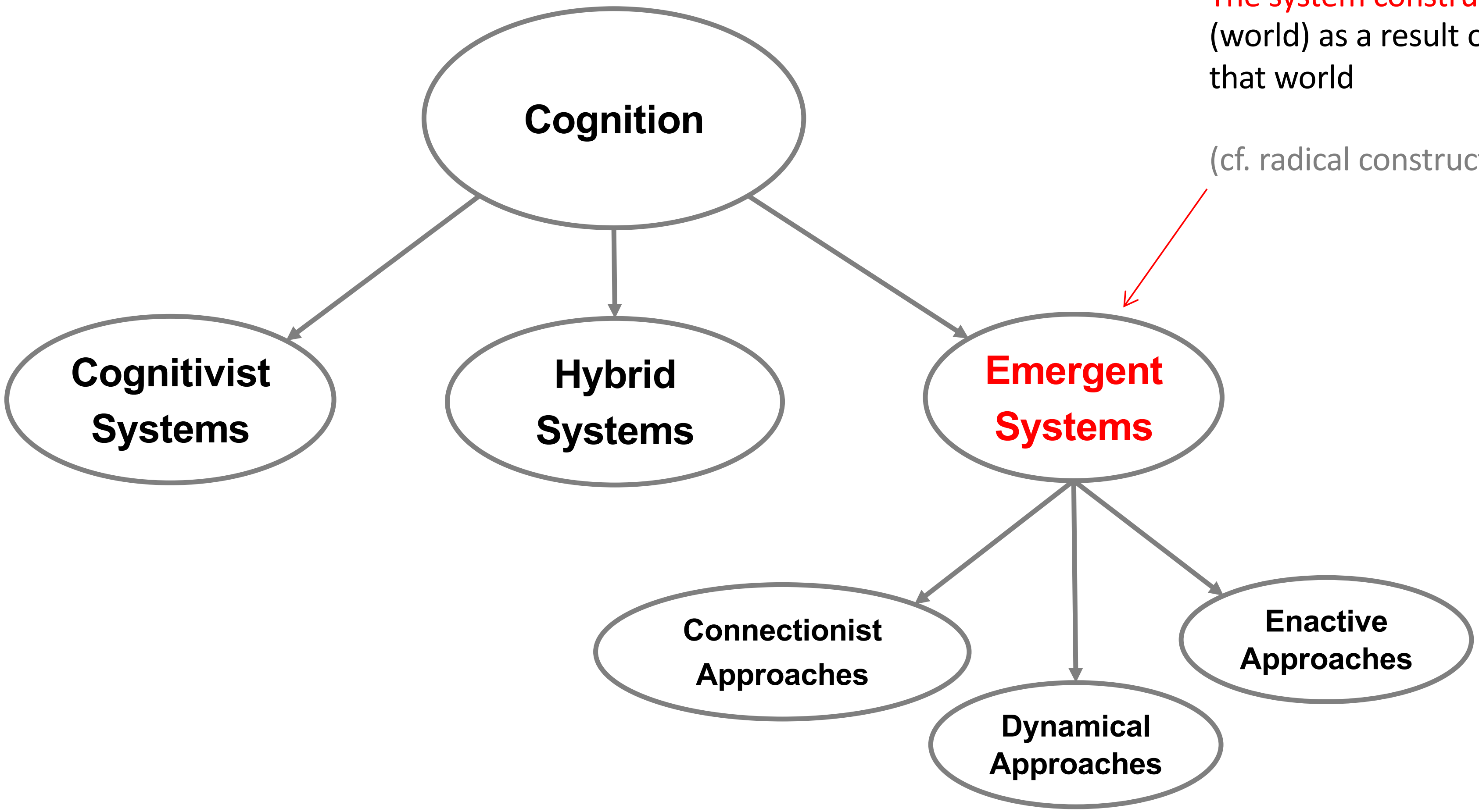


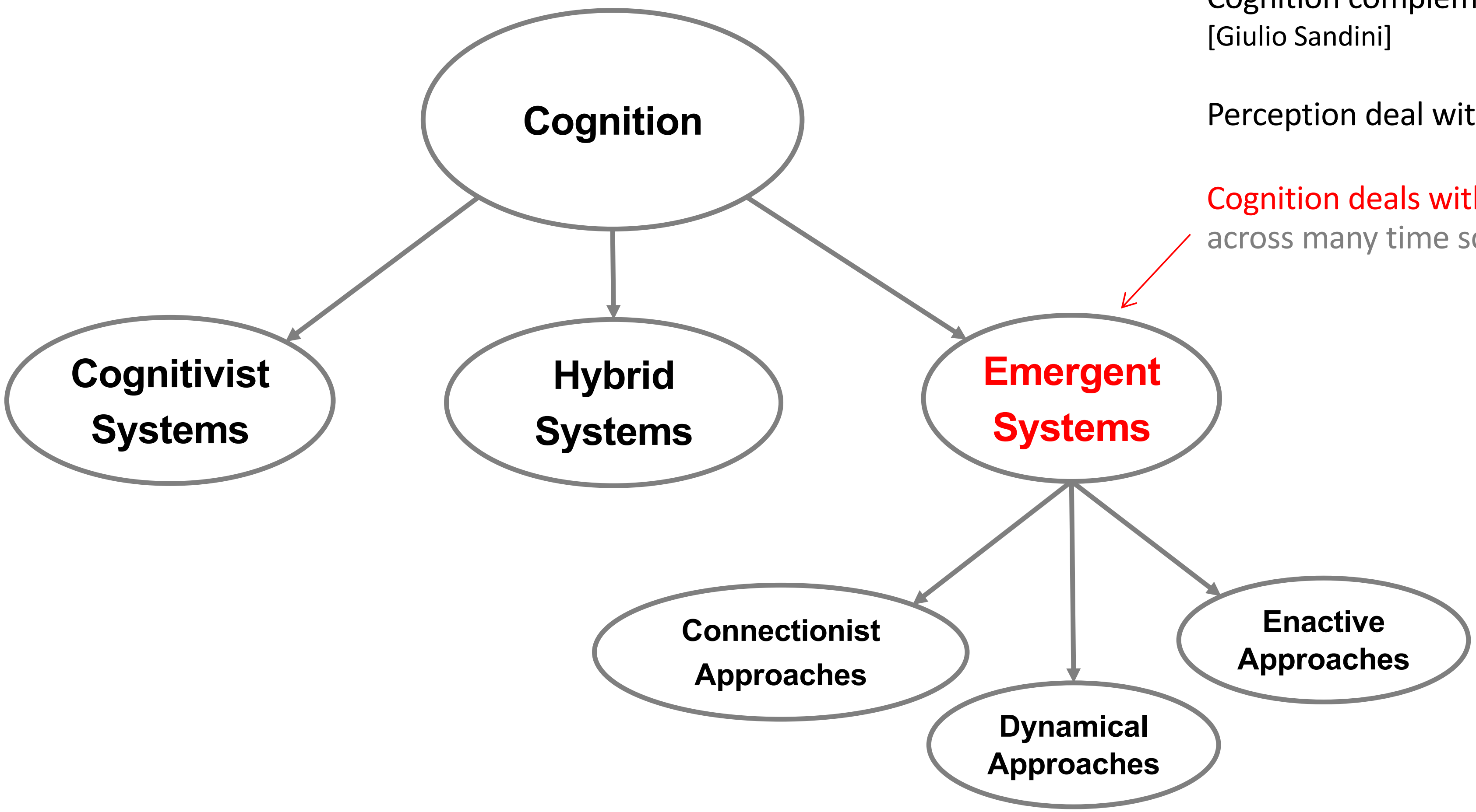
Cognition is the process whereby an autonomous system becomes viable and effective in its environment

Maturana and Varela 1987

The system constructs its reality (world) as a result of its operation in that world

(cf. radical constructivism)



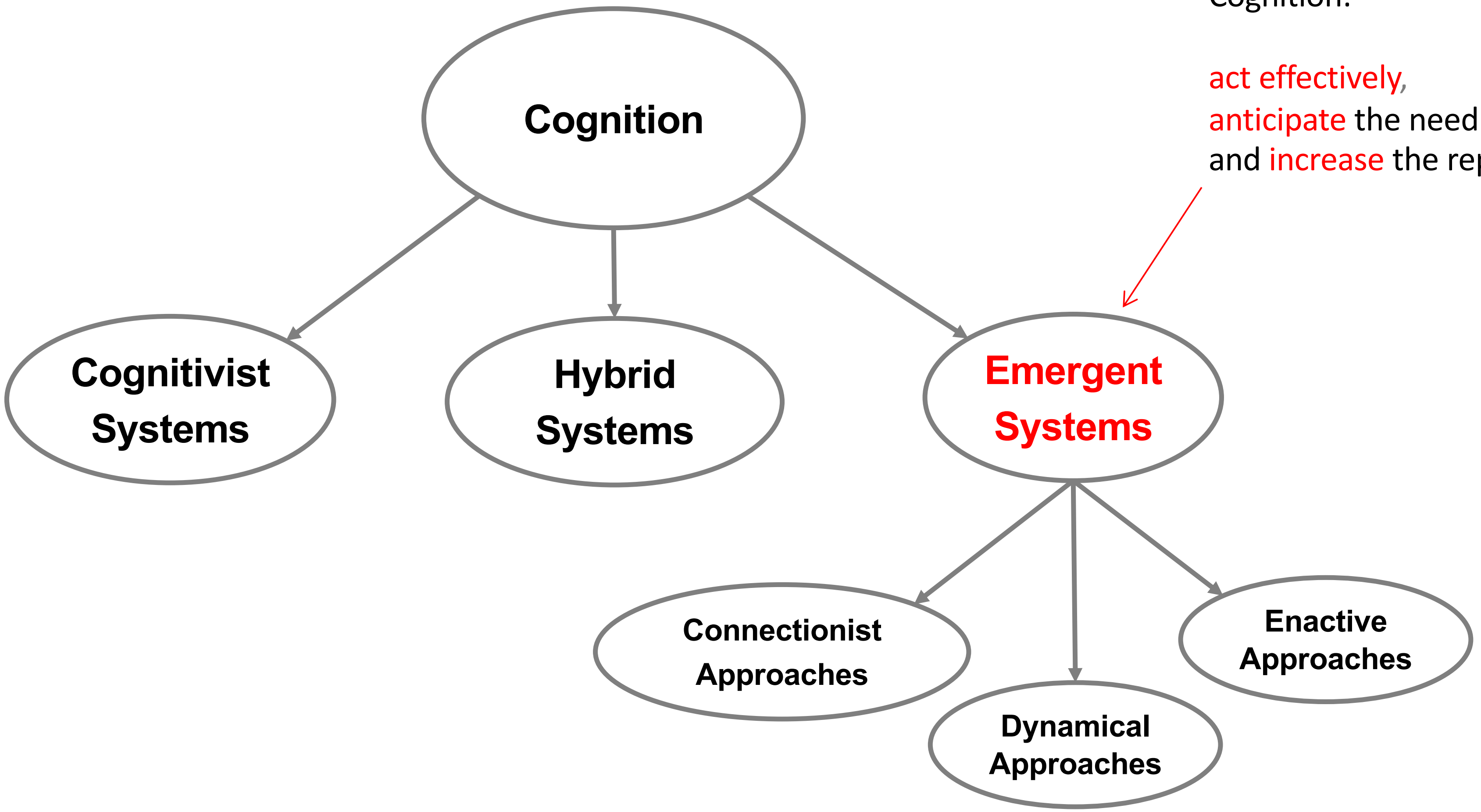


Cognition complements perception
[Giulio Sandini]

Perception deal with the immediate

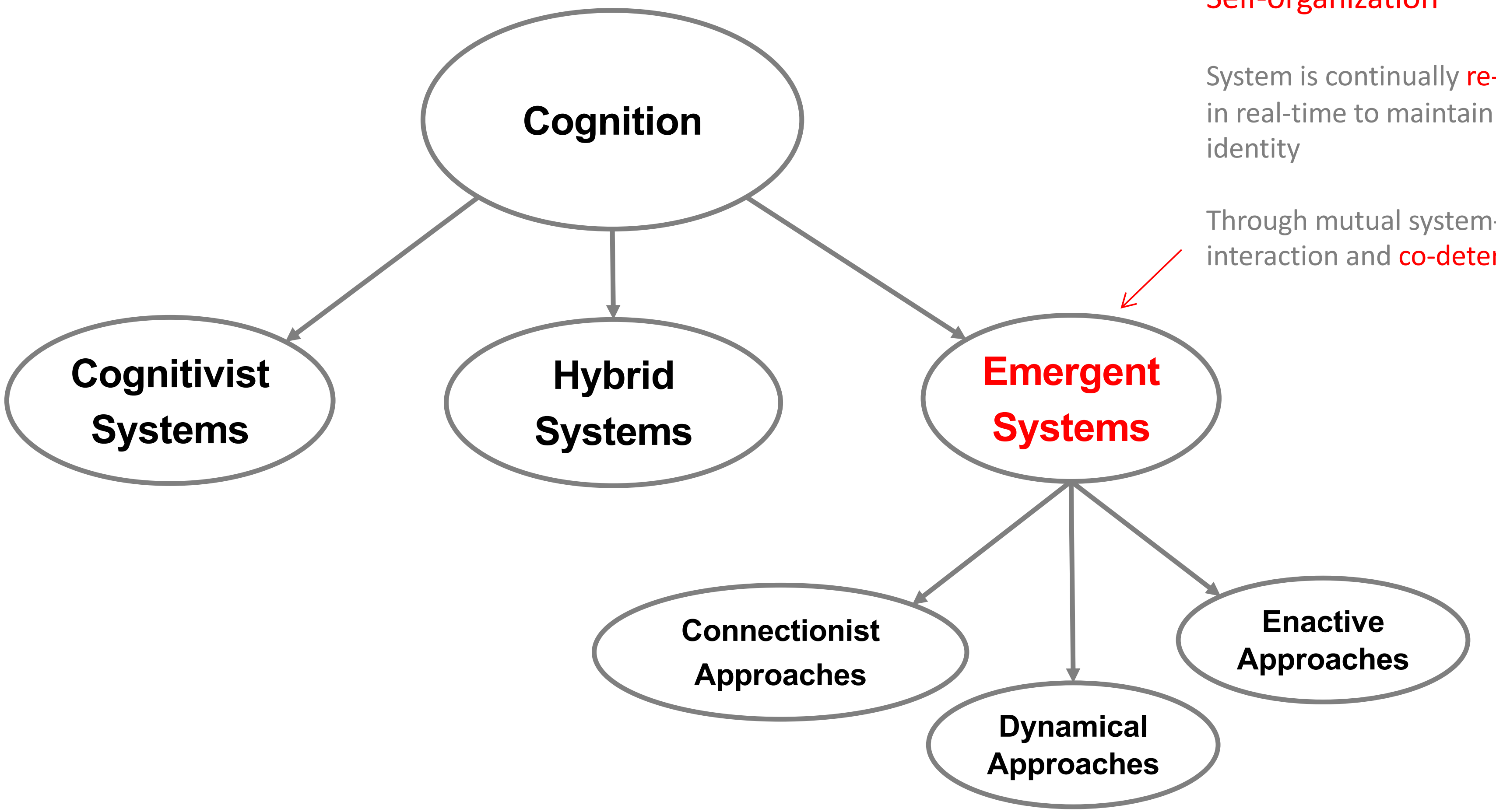
Cognition deals with the future
across many time scales

The Future



Cognition:

act effectively,
anticipate the need to act,
and increase the repertoire of actions

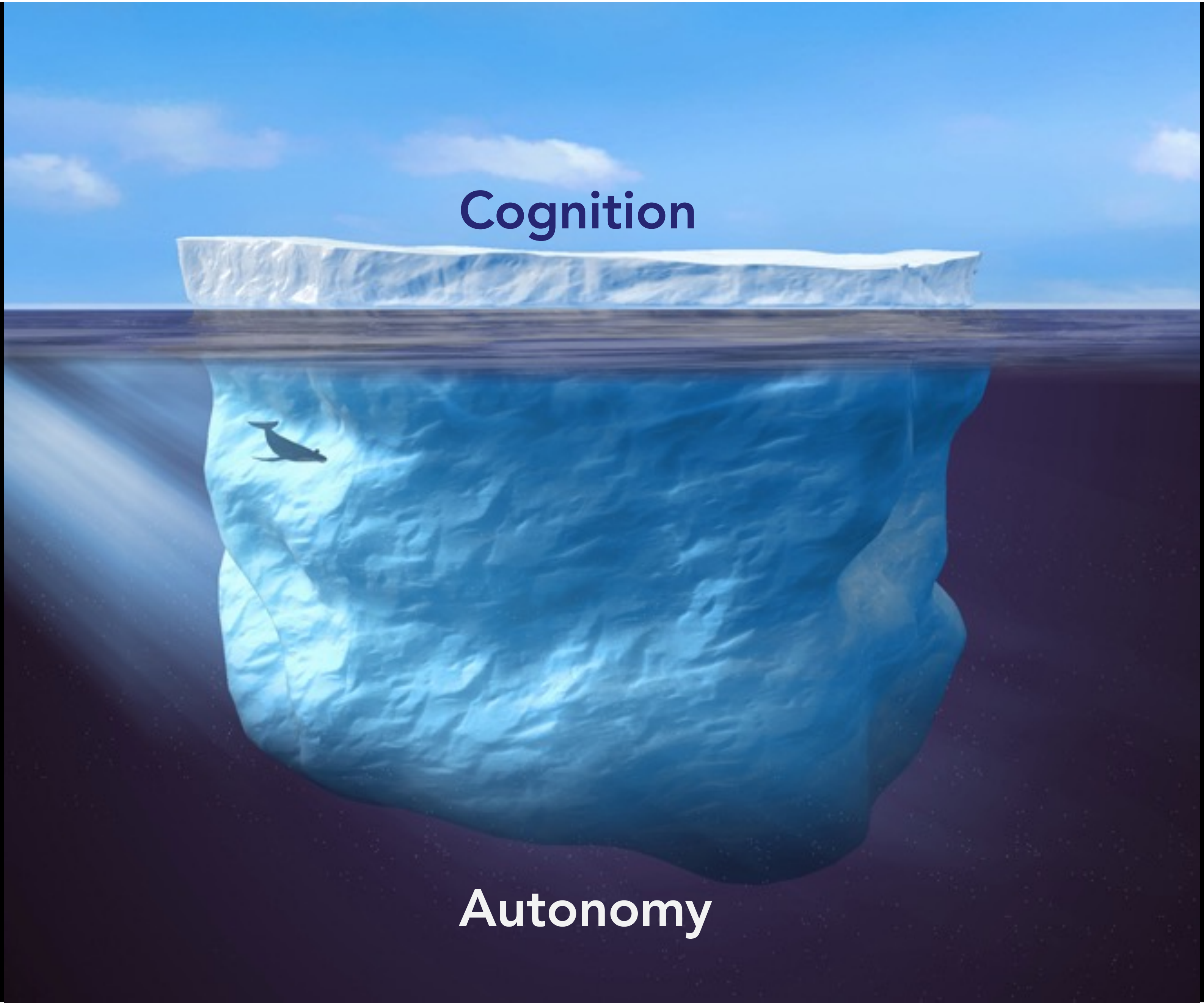


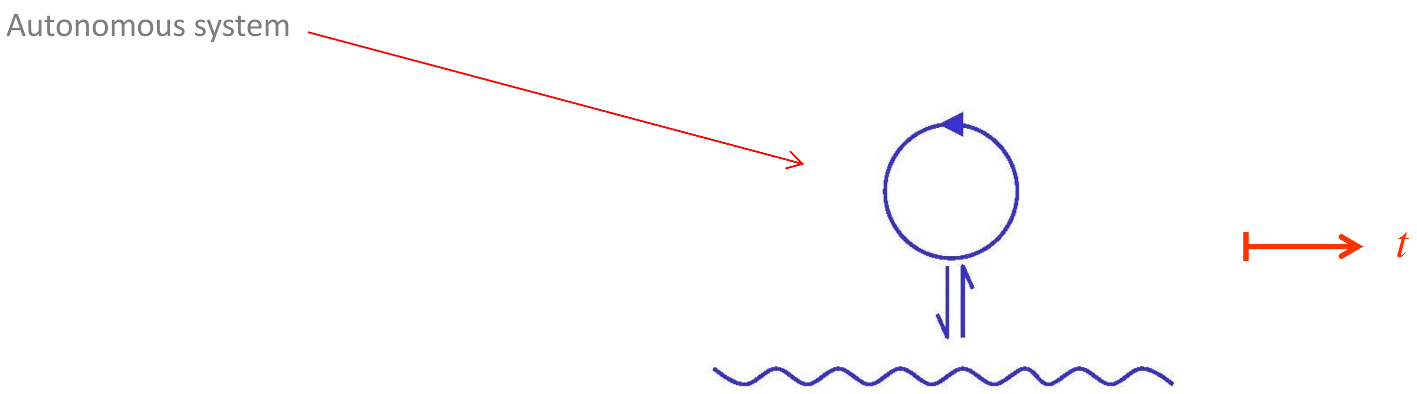
Self-organization

System is continually re-constituting itself in real-time to maintain it operational identity

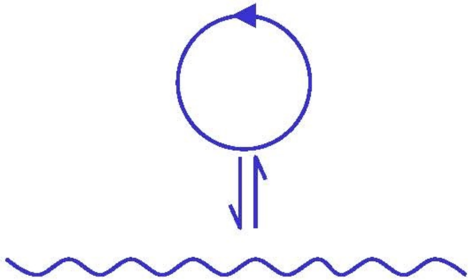
Through mutual system-environment interaction and co-determination

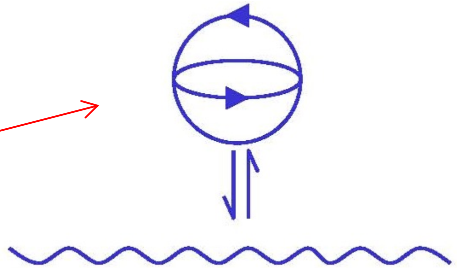

Cognition


Cognition
Autonomy



[Note: this ideogram and similar ones to follow were introduced in Maturana and Varela 1987]

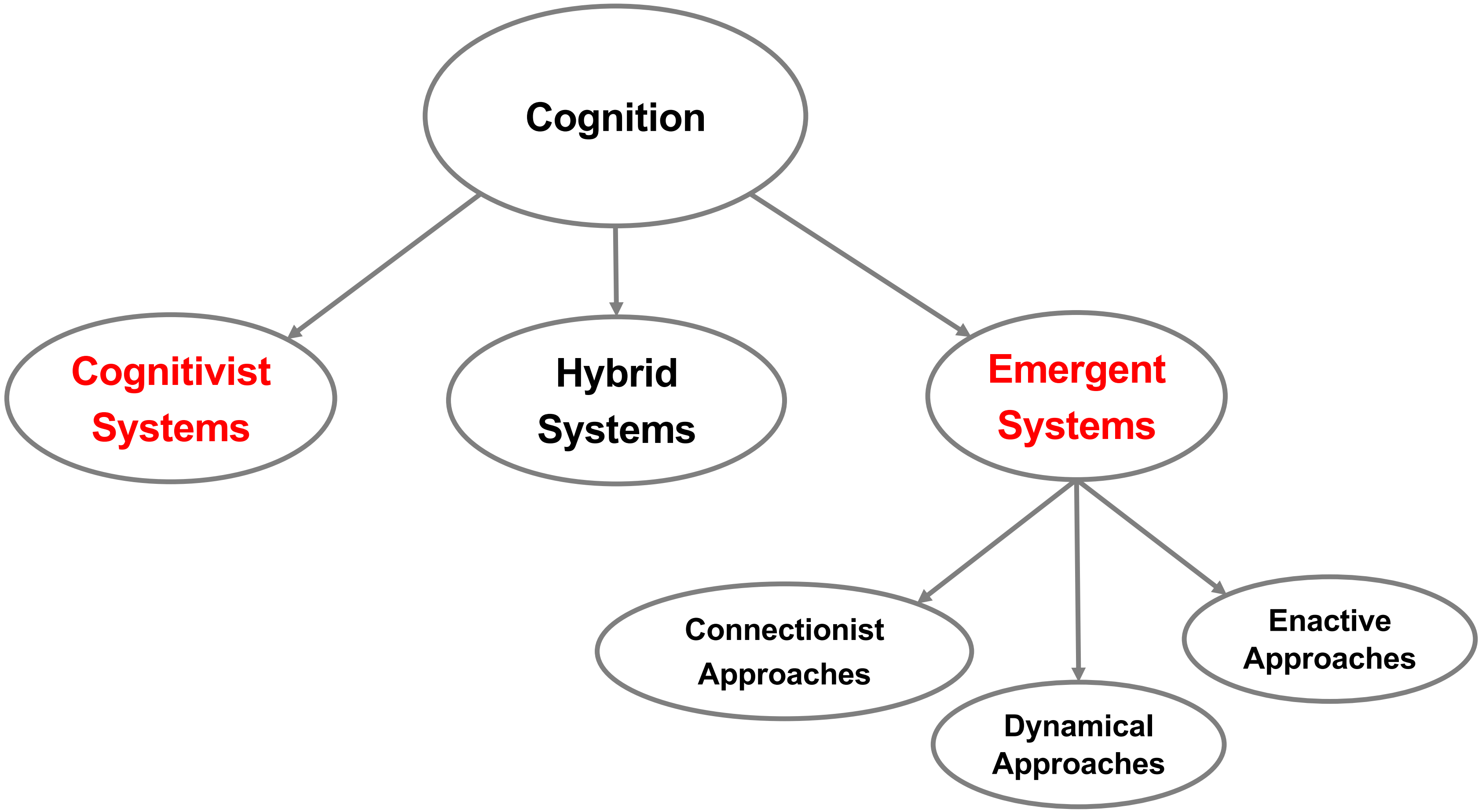




Anticipation / Planning / Explanation / Prediction

Autonomous system
with a nervous system
capable of development

[Note: this ideogram and similar ones to follow were introduced in Maturana and Varela 1987]


Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches

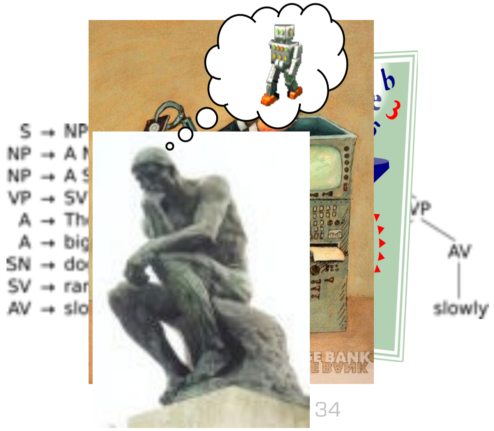
Differences between Cognitivist & Emergent Paradigms

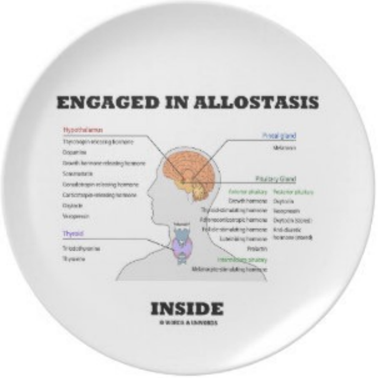
1. Computational operation
2. Representational framework
3. Semantic grounding
4. Temporal constraints
5. Inter-agent epistemology
6. Embodiment
7. Perception
8. Action
9. Anticipation
10. Adaptation
11. Motivation
12. Autonomy
13. Cognition
14. Philosophical foundation

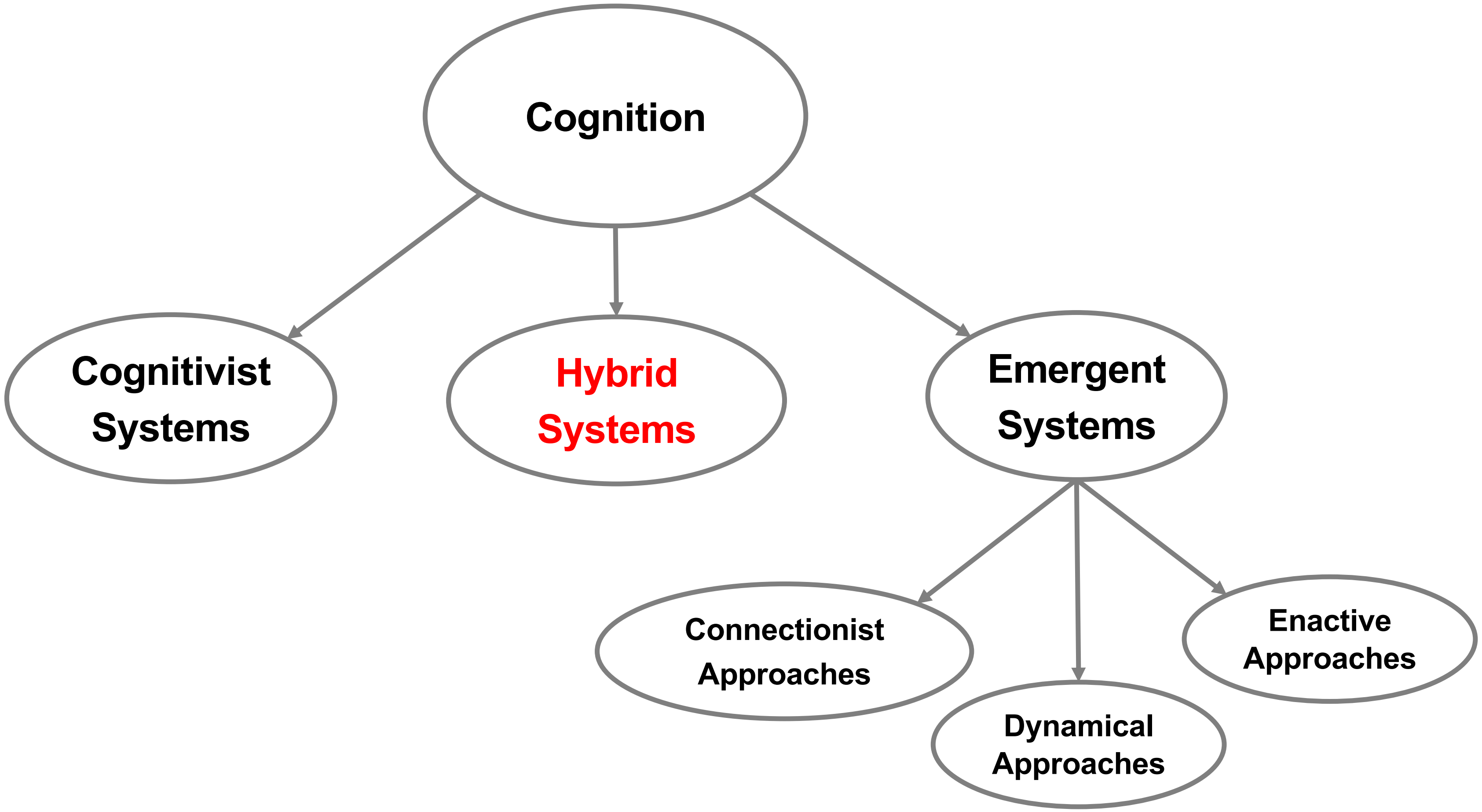
[Vernon, Von Hofsten, Fadiga 2010]

The Cognitivist Paradigm vs. the Emergent Paradigm

Characteristic	Cognitivist	Emergent
Computational Operation	Syntactic manipulation of symbols	Concurrent self-organization of a network
Representational Framework	Patterns of symbol tokens	Global system states
Semantic Grounding	Percept-symbol association	Skill construction
Temporal Constraints	Atemporal	Synchronous real-time entrainment
Inter-agent epistemology	Agent-independent	Agent-dependent
Embodiment	No role implied: functionalist	Direct constitutive role: non-functionalist
Perception	Abstract symbolic representations	Perturbation by the environment
Action	Causal consequence of symbol manipulation	Perturbation by the system
Anticipation	Procedural or probabilistic reasoning	Traverse of perception-action state space
Adaptation	Learn new knowledge	Develop new dynamics
Motivation	Criteria for goal selection	Increase space of interaction
Autonomy	Not entailed	Cognition entails autonomy
Cognition	Rational goal-achievement	Self-maintenance and self-development
Philosophical Foundation	Positivism	Phenomenology






Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches

Hybrid Models

H vs h

Hybrid Models

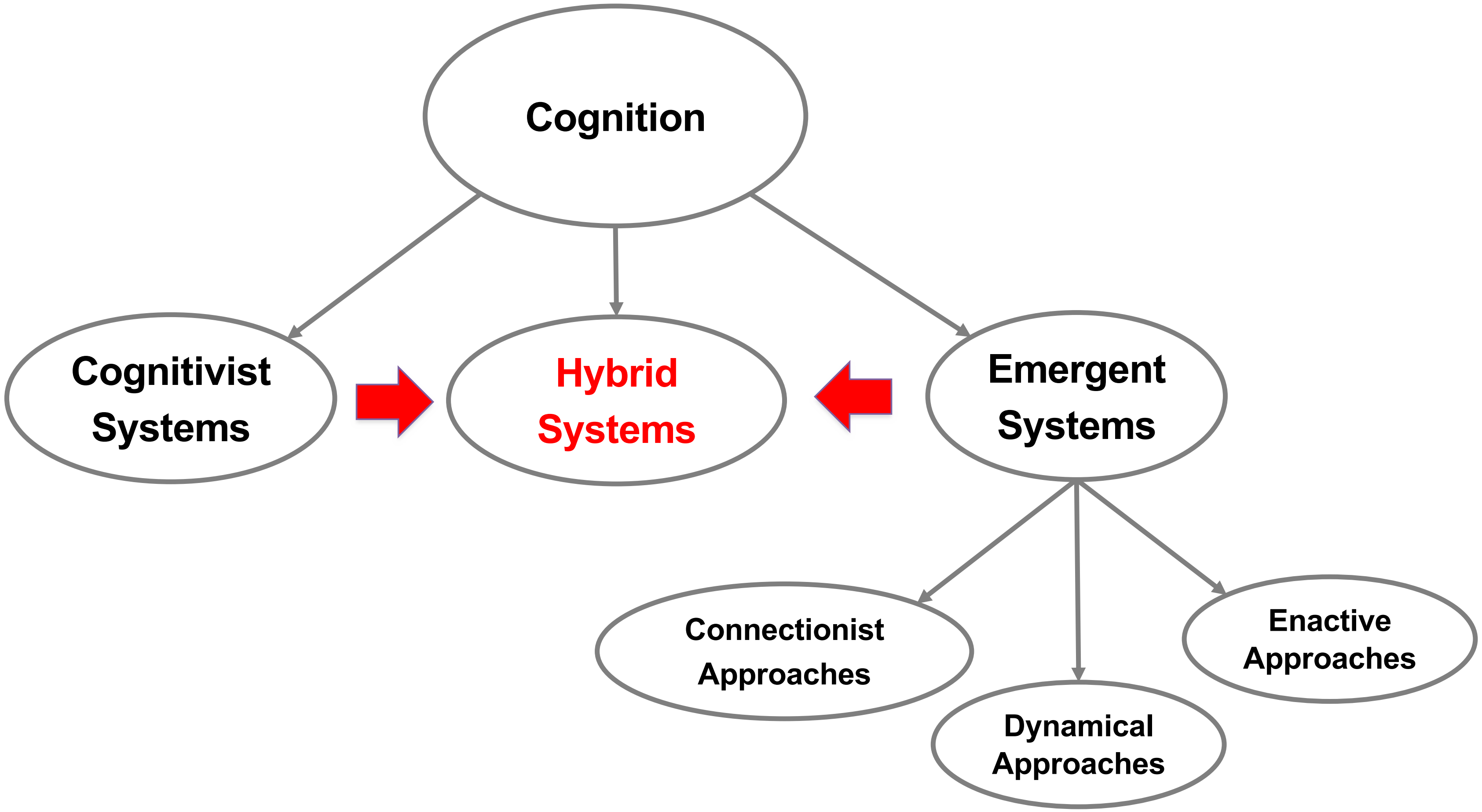
H vs h

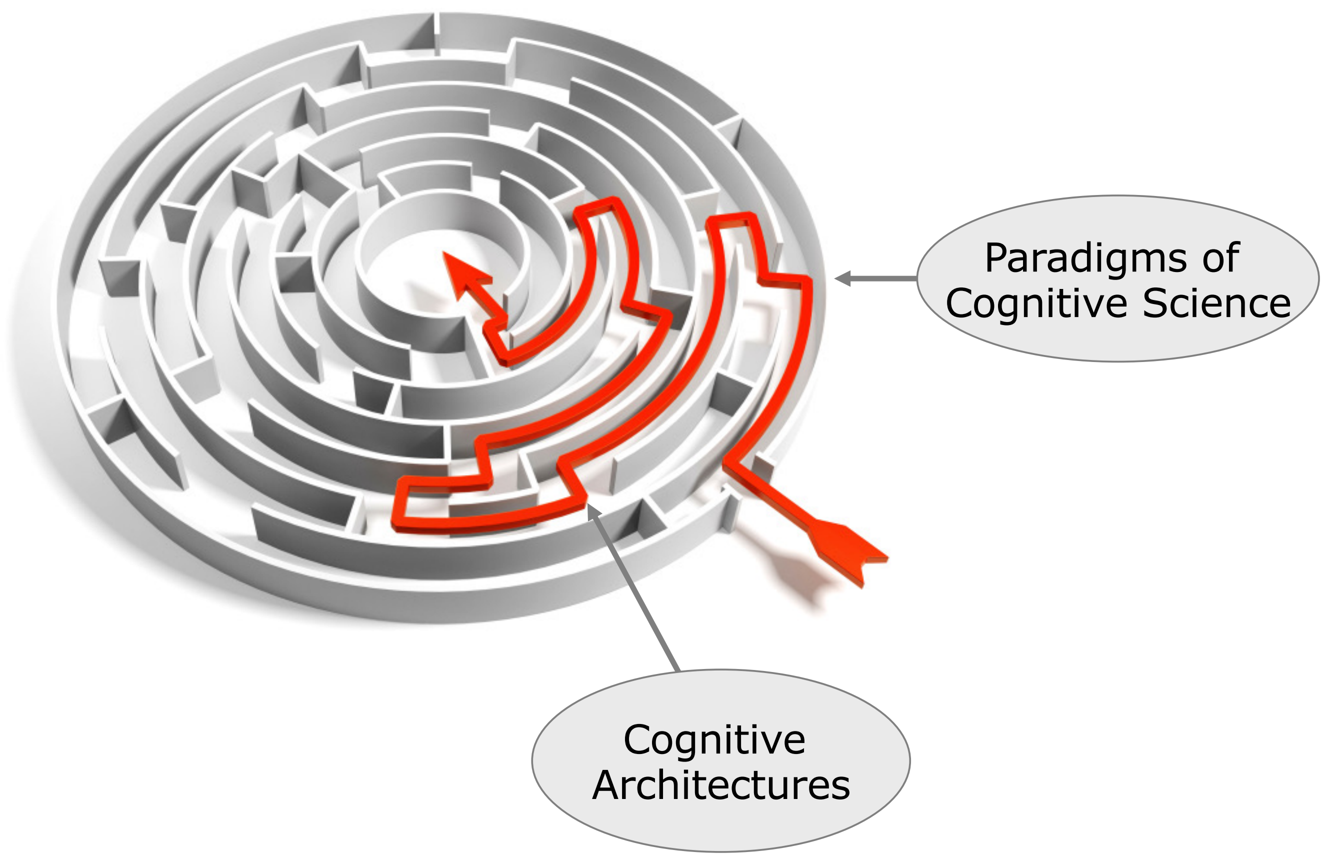
Reconcile all differences,
including antagonistic
philosophical foundations

Hybrid Models

H vs h

Symbolic & sub-symbolic


Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches


Paradigms of
Cognitive Science
Cognitive
Architectures

Cognitive Architectures Forums

http://bicasociety.org/

Biologically Inspired Cognitive Architectures

› Supports Open Access

Editor in Chief: A. Samsonovich

https://www.journals.elsevier.com/biologically-inspired-cognitive-architectures/

Cognitive Systems Research

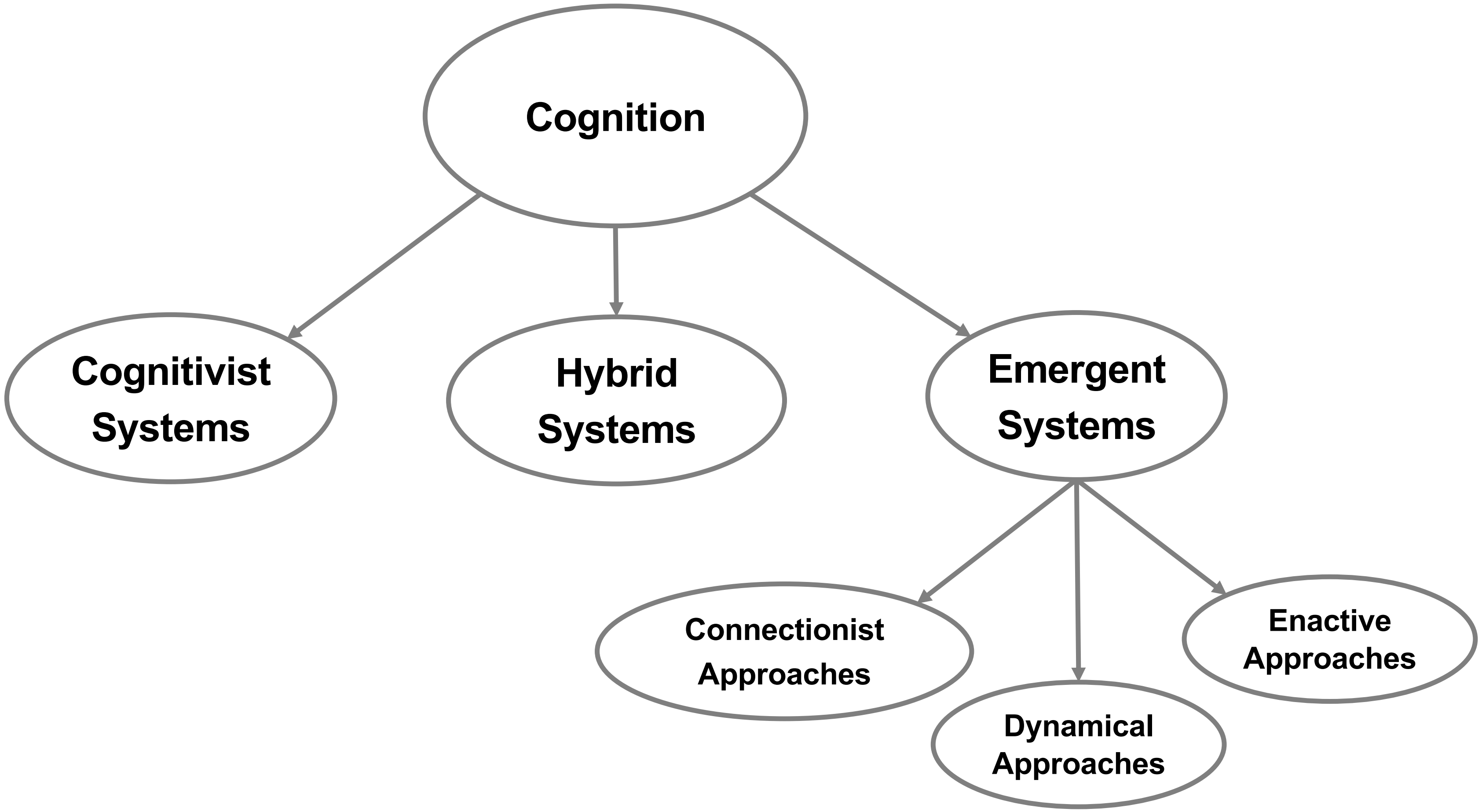
Editor-in-Chief: T. R. Besold

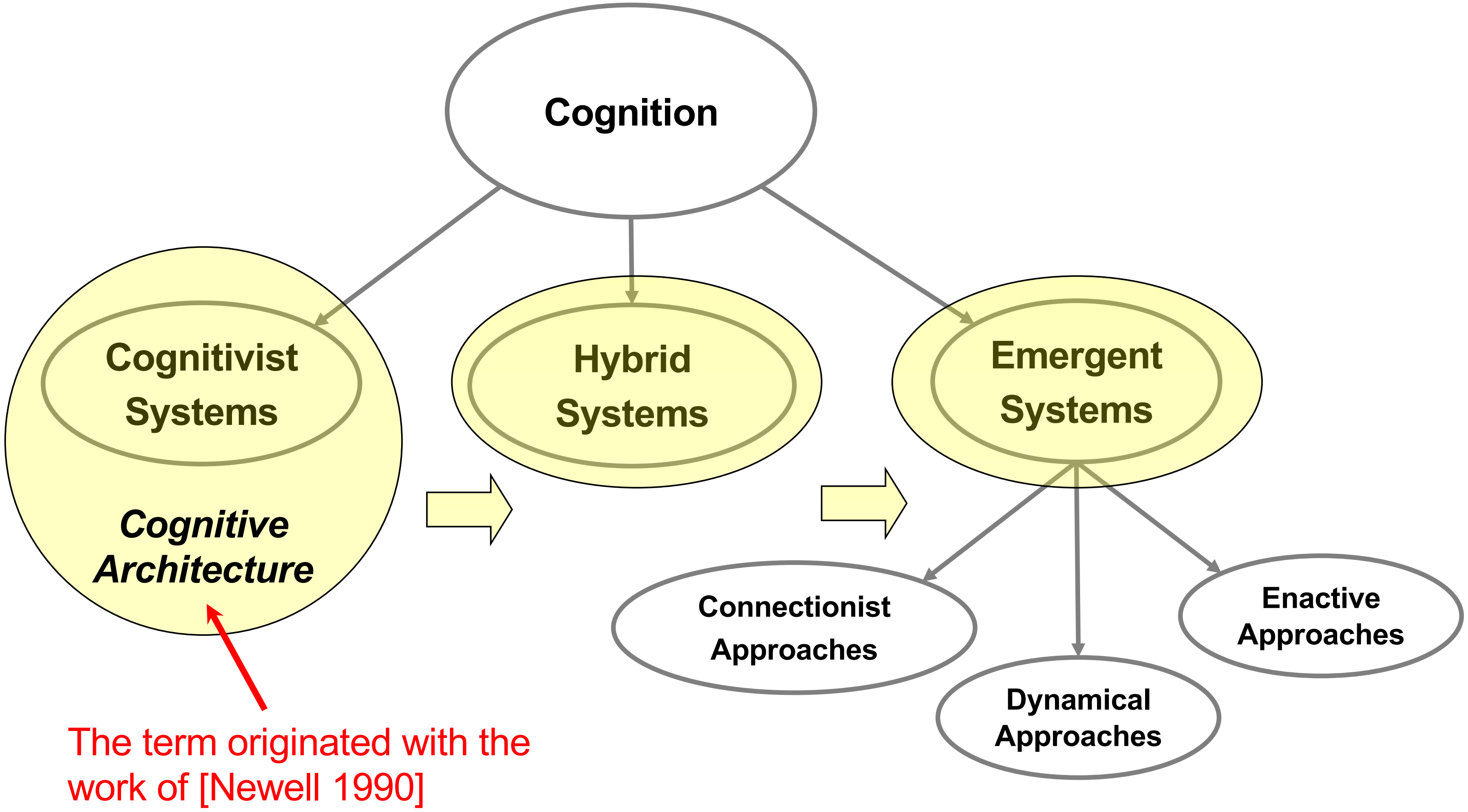
› View Editorial Board

› **CiteScore: 3.2** ⓘ **Impact Factor: 1.902** ⓘ

ISSN: 1389-0417

https://www.journals.elsevier.com/cognitive-systems-research


Cognition
Cognitivist Systems
Hybrid Systems
Emergent Systems
Connectionist Approaches
Dynamical Approaches
Enactive Approaches


Cognition
Cognitivist
Systems
Cognitive
Architecture
Hybrid
Systems
Emergent
Systems
Connectionist
Approaches
Dynamical
Approaches
Enactive
Approaches
The term originated with the
work of [Newell 1990]

DRAFT MATERIAL: LIMITED DISTRIBUTION FOR COMMENT.
NOT FOR QUOTATION
File: C3HCA.MSS
Current version: 04 August 87 17:44
Started: 25 Jul 87

The 1987 William James Lectures
UNIFIED THEORIES OF COGNITION

CHAPTER 3
HUMAN COGNITIVE ARCHITECTURE

DRAFT 1

Allen Newell

4 August 1987

Departments of Computer Science and Psychology
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

http://digitalcollections.library.cmu.edu/awweb/awarchive?type=file&item=352120

Cognitivist Cognitive Architecture

Attempts to create **Unified Theories of Cognition (UTC)**

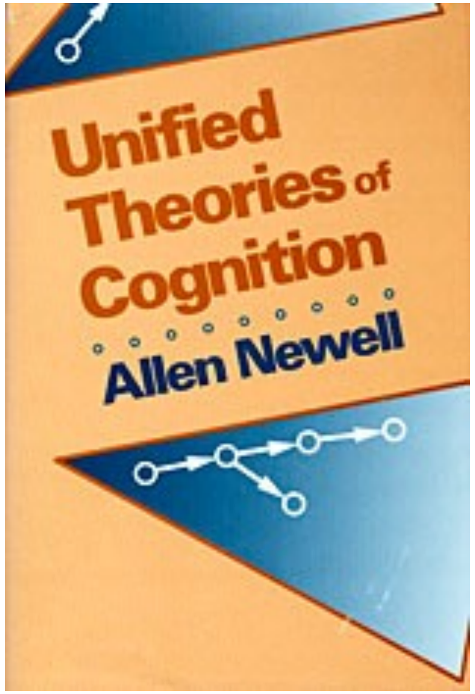
UTCs cover a broad range of cognitive issues:

- Attention
- Memory
- Problem solving
- Decision making
- Learning
- ...

from several aspects:

- Psychology
- Neuroscience
- Computer Science
- ...

[Byrne 03]



Cognitivist Cognitive Architecture

An embodiment of a **scientific hypothesis** about those aspects of **human cognition** that are:

- relatively **constant over time** and
- relatively **independent of task**

[Ritter & Young 2001]

Cognitivist Cognitive Architecture

- Generic computational model:
  - Not domain-specific
  - Not task-specific
- Knowledge provides the required specificity:

Cognitive Architecture + Knowledge = **Cognitive Model**

[Lehman et al. 1997, also Anderson & Labiere 1998, Newell 1990]

Cognitivist Cognitive Architecture

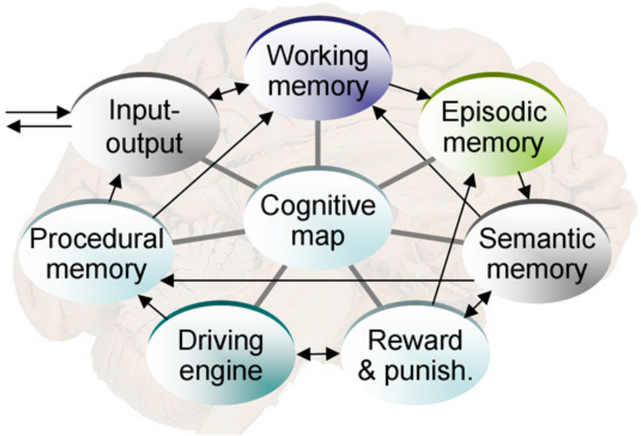
Overall structure and organization of a cognitive system

- Essential Modules
- Essential relations between these modules
- Essential algorithmic and representational details in each module

[Sun 2007]

Commitment to formalisms for representation and processes

[Langley 2005, Langley 2006, Langley et al. 2009]



[GMU-BICA Architecture: Samsonovich 2005]

Emergent Cognitive Architecture

Emergent approaches focus on development

- From a primitive state
- To fully cognitive state, over the system's lifetime

Emergent Cognitive Architecture

- Two different views of development
  - Individual
  - Social
- Two different theories of cognitive development
  - Jean Piaget (1896–1980)
  - Lev Vygotsky (1896–1934)

Emergent Cognitive Architecture

The cognitive architecture is the system's **phylogenetic configuration**

- The basis for ontogenesis: growth and development
  - Innate skills
  - Core knowledge (cf. Spelke)
- A structure in which to embed mechanisms for
  - Perception
  - Action
  - Adaptation
  - Anticipation
  - Motivation
  - … Development of all these

Emergent Cognitive Architecture

Strong focus on

- **Autonomy-preserving**
  anticipatory
  adaptive
  skill construction

- The **morphology** of the physical body
  in which the architecture is embedded

Emergent Cognitive Architecture

The emergent approach rejects:

- **Dualism** between mind and body

- **Functionalism** that treats cognitive mechanisms independently of the physical platform

    - Computational functionalism

    - Robotic functionalism

Ziemke, T., The body of knowledge: On the role of the living body in grounding embodied cognition. BioSystems (2016), http://dx.doi.org/10.1016/j.biosystems.2016.08.005

Desirable Characteristics of a Cognitive Architecture

Desirable Characteristics

- Realism
- Behavioral Characteristics
- Cognitive Characteristics

PHILOSOPHICAL PSYCHOLOGY, VOL. 17, NO. 3, SEPTEMBER 2004

Routledge
Taylor & Francis Group

Desiderata for cognitive architectures

RON SUN

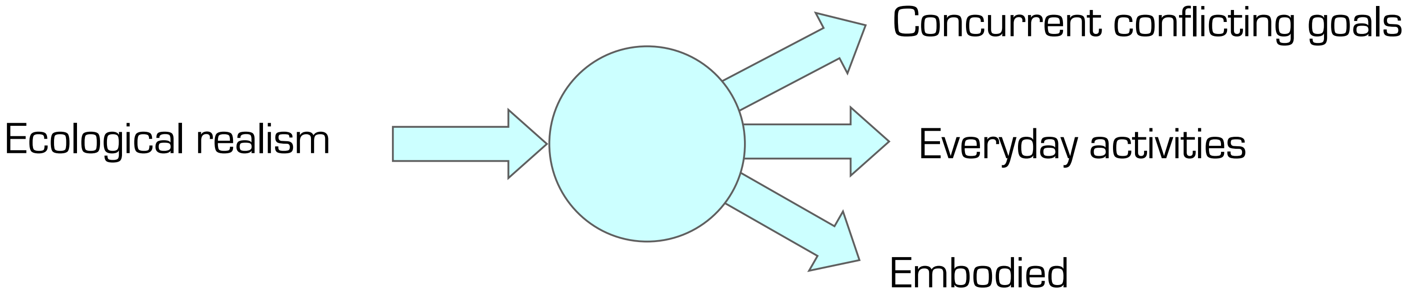
- Functional Capabilities [Langley et al. 2009, Sun 2007]
- Development [Krichmar & Edelman 2006, 2007; Vernon et al. 2016]
- Dynamics

Desirable Characteristics

Realism [Sun 2004]:

1. Ecological realism
2. Bio-evolutionary realism
3. Cognitive realism
4. Inclusiveness of prior perspectives

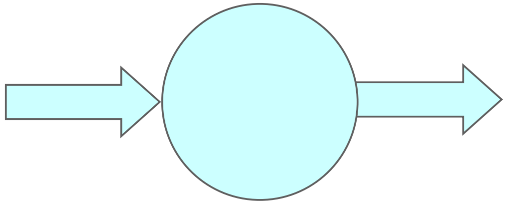
Desirable Characteristics



[Sun 2004]

Desirable Characteristics

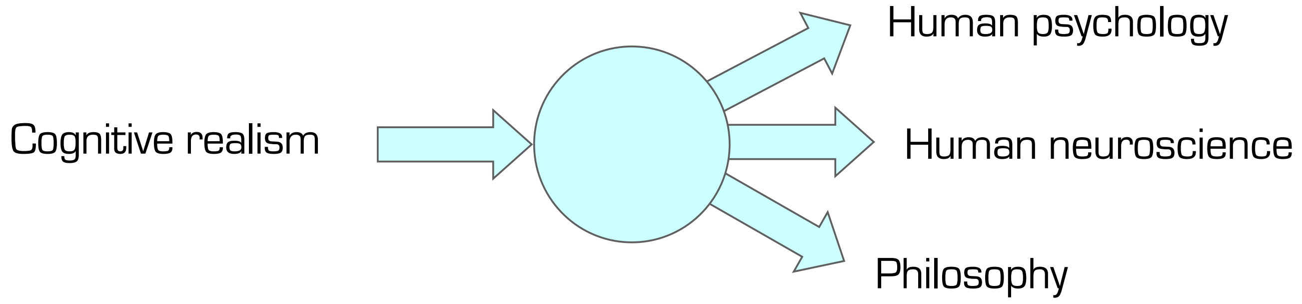
Bio-evolutionary realism



Human intelligence reducible to
model of animal intelligence

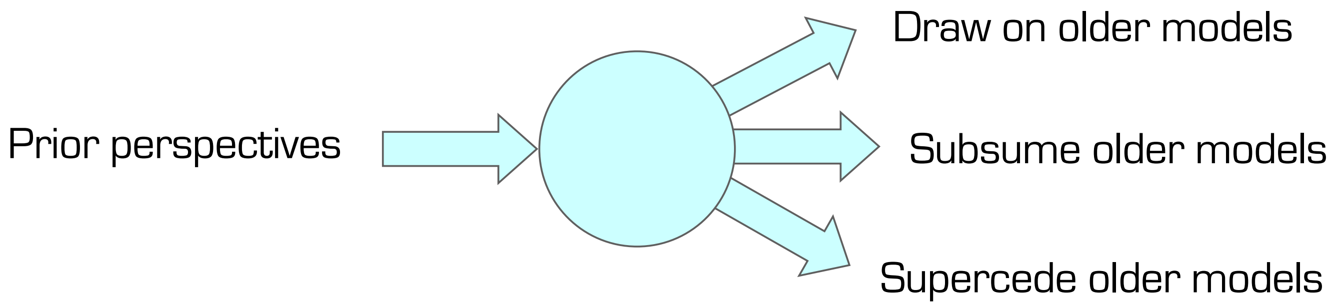
[Sun 2004]

Desirable Characteristics



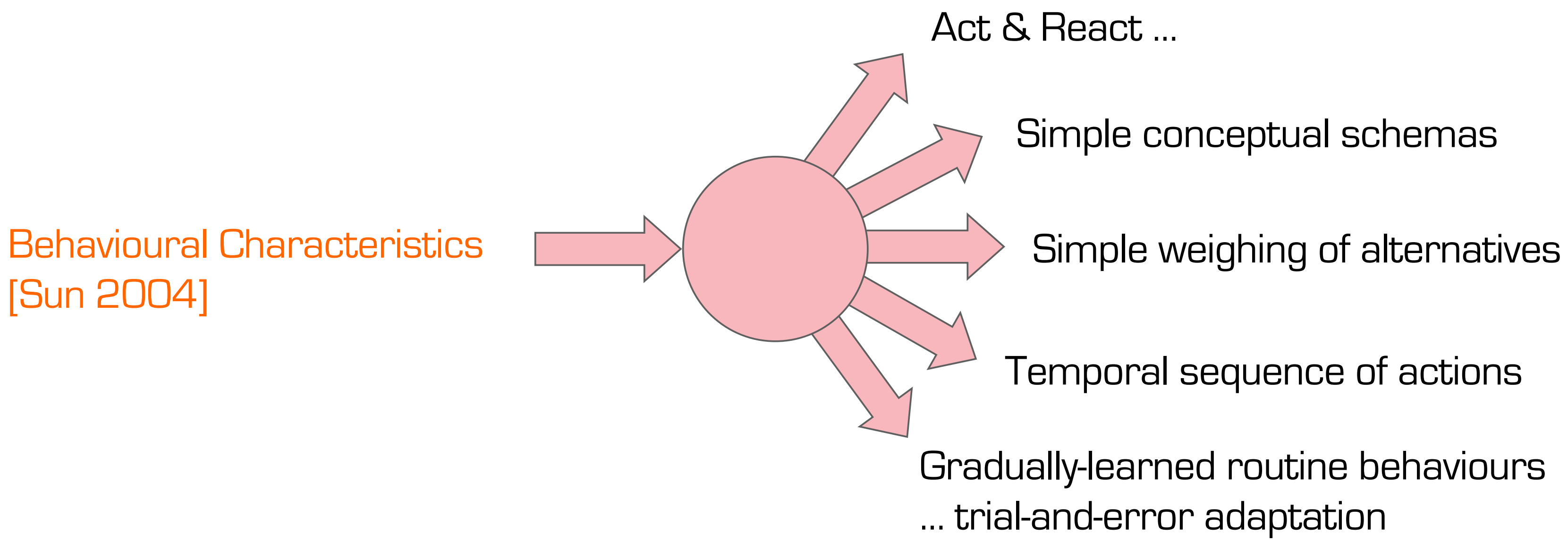
[Sun 2004]

Desirable Characteristics



[Sun 2004]

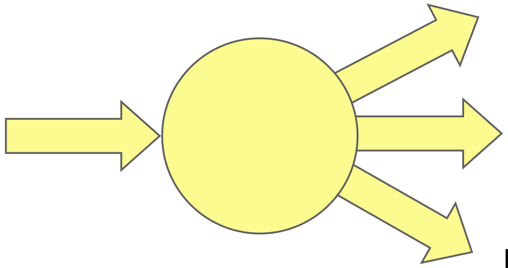
Desirable Characteristics



[Sun 2004]

Desirable Characteristics

Cognitive Characteristics
[Sun 2007]



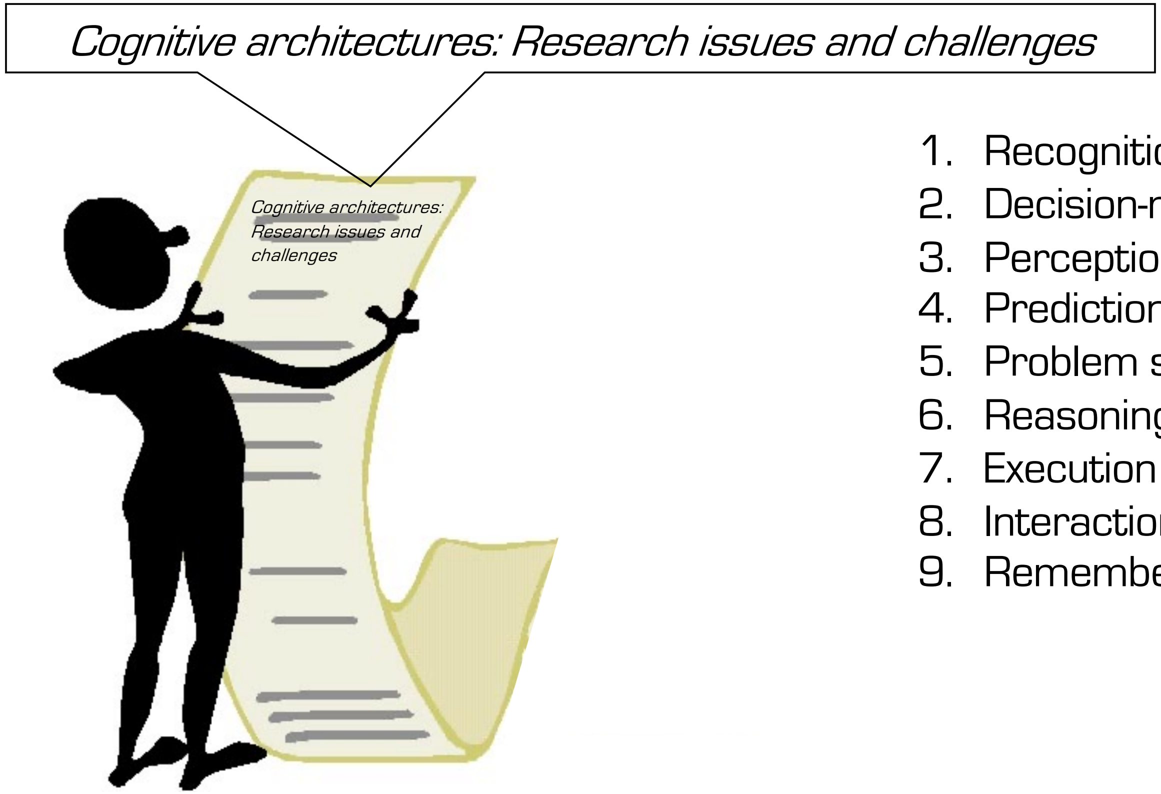
Implicit bottom-up learning

Explicit symbolic learning

Functional or physical modularity

[Sun 2004]

Desirable Characteristics



[Langley et al. 2009]

1. Recognition & categorization
2. Decision-making & choice
3. Perception & situation assessment
4. Prediction & monitoring
5. Problem solving & planning
6. Reasoning & belief maintenance
7. Execution & action
8. Interaction & communication
9. Remembering, reflection, & learning

Desirable Characteristics

The importance of cognitive architectures ...

[Sun 2007]

1. Perception
2. Categorization
3. Multiple representations
4. Multiple types of memory
5. Decision making
6. Reasoning
7. Planning
8. Problem solving
9. Meta-cognition
10. Communication
11. Action control and execution
12. Several types of learning

The importance of the interconnectivity between these processes

Desirable Characteristics

PHILOSOPHICAL PSYCHOLOGY, VOL. 17, NO. 3, SEPTEMBER 2004

Routledge
Taylor & Francis Group

Desiderata for cognitive architectures

RON SUN

Biologically Inspired Cognitive Architectures

Volume 18, October 2016, Pages 116–127

Research article

Desiderata for developmental cognitive architectures

David Vernon[a], Claes von Hofsten[b], Luciano Fadiga[c, d]

Show more

http://dx.doi.org/10.1016/j.bica.2016.10.004

Get rights and content

Desirable Characteristics

Development

Desideratum 1. Value systems and motives

Desideratum 2. Physical embodiment

Desideratum 3. Sensorimotor contingencies

Desideratum 4. Perception

Desideratum 5. Attention

Desideratum 6. Prospective action

Desideratum 7. Declarative and procedural memory

Desideratum 8. Multiple modes of learning

Desideratum 9. Internal simulation

Desideratum 10. Constitutive autonomy

ELSEVIER
Biologically Inspired Cognitive Architectures
Volume 18, October 2016, Pages 116–127

Research article

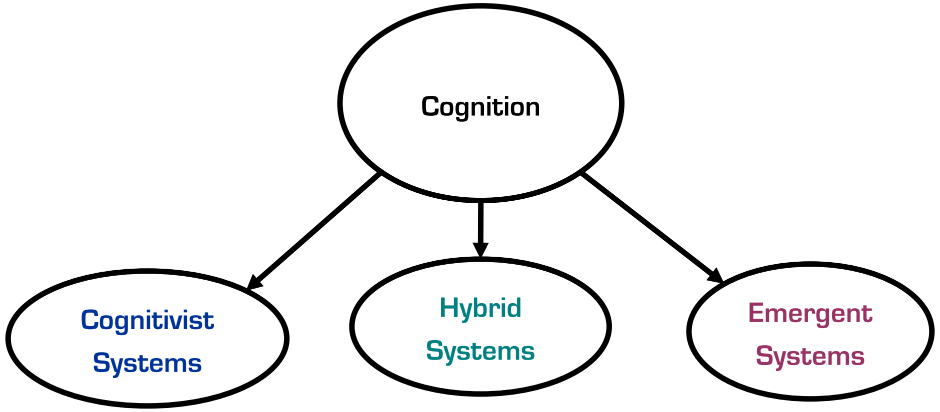
Desiderata for developmental cognitive architectures

David Vernon[a], Claes von Hofsten[b], Luciano Fadiga[c, d]
Show more

http://dx.doi.org/10.1016/j.bica.2016.10.004

Organizational decomposition

- Explicit inter-connectivity
- Representational formalism
- Algorithmic formalism



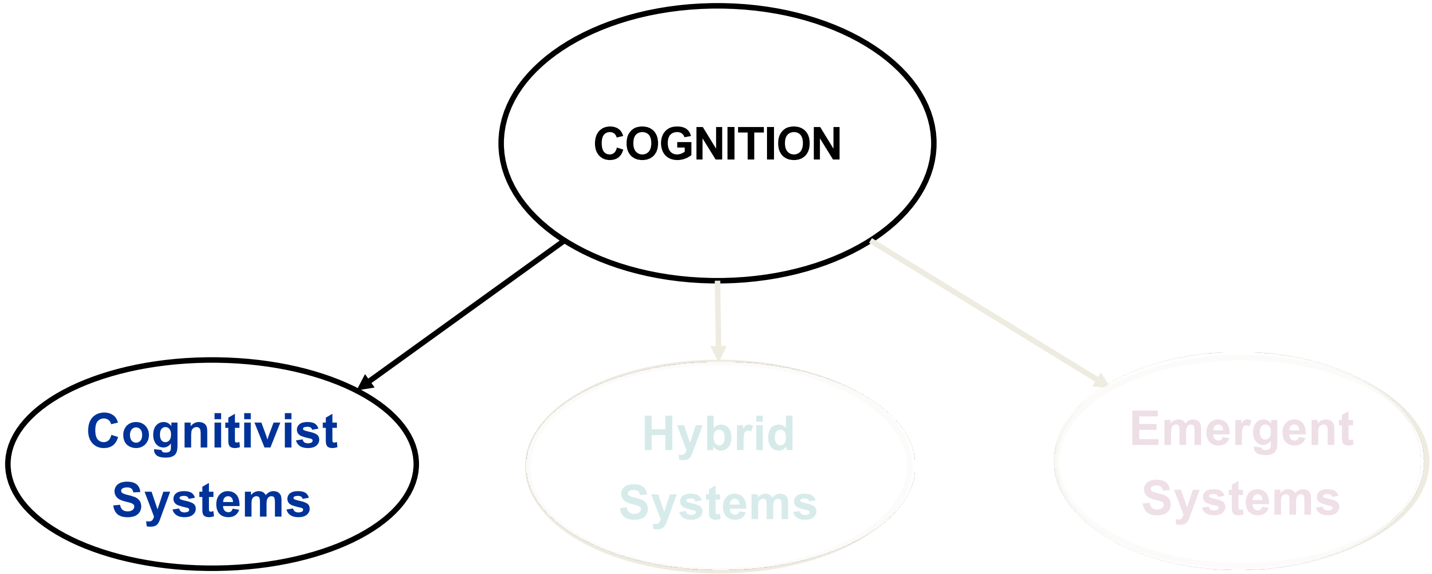
Framework in which to embed knowledge

- Memories
- Formalisms for learning
- Programming mechanism

Phylogeny - basis for development

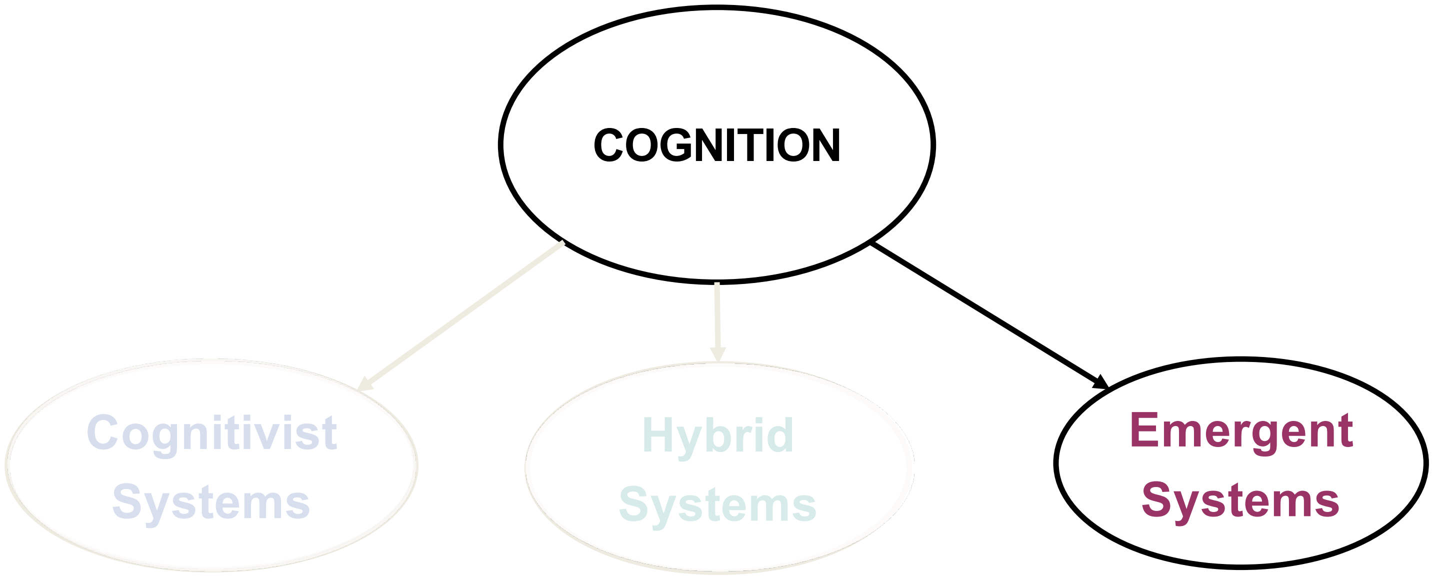
- Innate skills & core knowledge
- Memories
- Formalism for autonomy
- Formalism for development

Example Cognitive Architectures



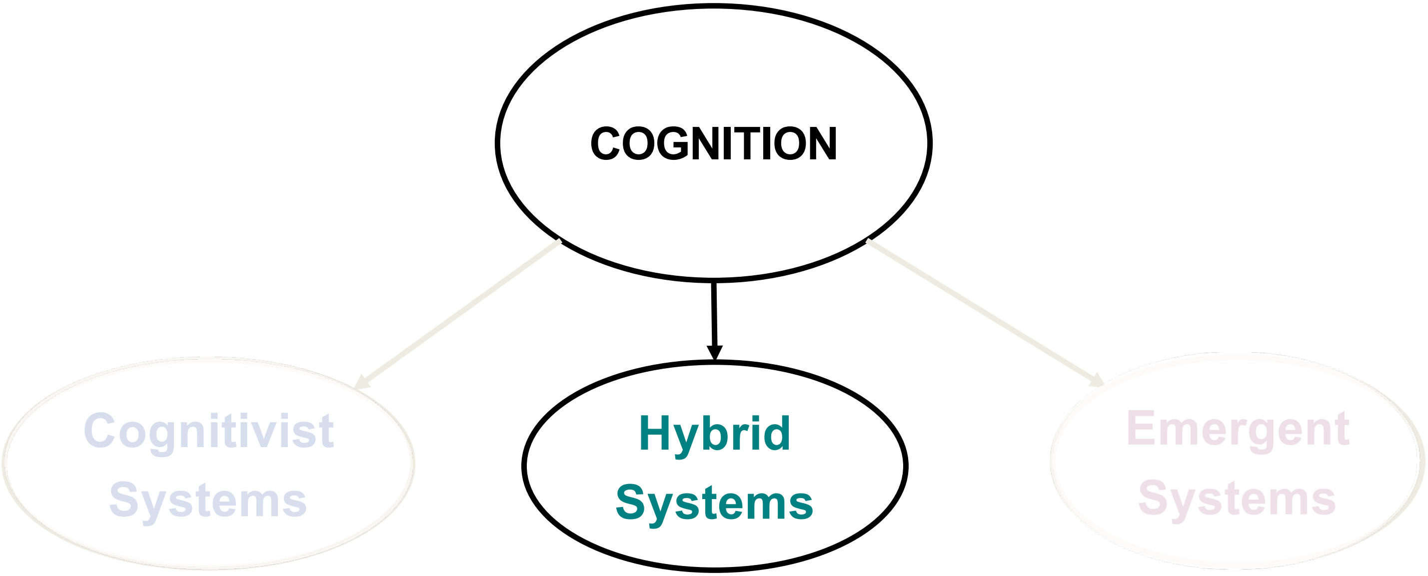
Soar [Newell 1996]
EPIC [Kieras & Meyer 1997]
ICARUS [Langley 05, Langley 2006]
GLAIR [Shapiro & Bona 2009]
CoSy [Hawes & Wyatt 2008]

Example Cognitive Architectures



iCub [Vernon et al. 2010]
Global Workspace [Shanahan 2006]
SASE [Weng 2004]
Darwin [Krichmar et al. 2005]
Cognitive Affective [Morse et al 2008]

Example Cognitive Architectures



CLARION [Sun 2007]
CRAM [Beetz et al. 2010]
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]

Example Cognitive Architectures

Surveys:

Biologically Inspired Cognitive Architectures Society, Comparative Repository of Cognitive Architectures, http://bicasociety.org/cogarch/architectures.htm (25 cognitive architectures)

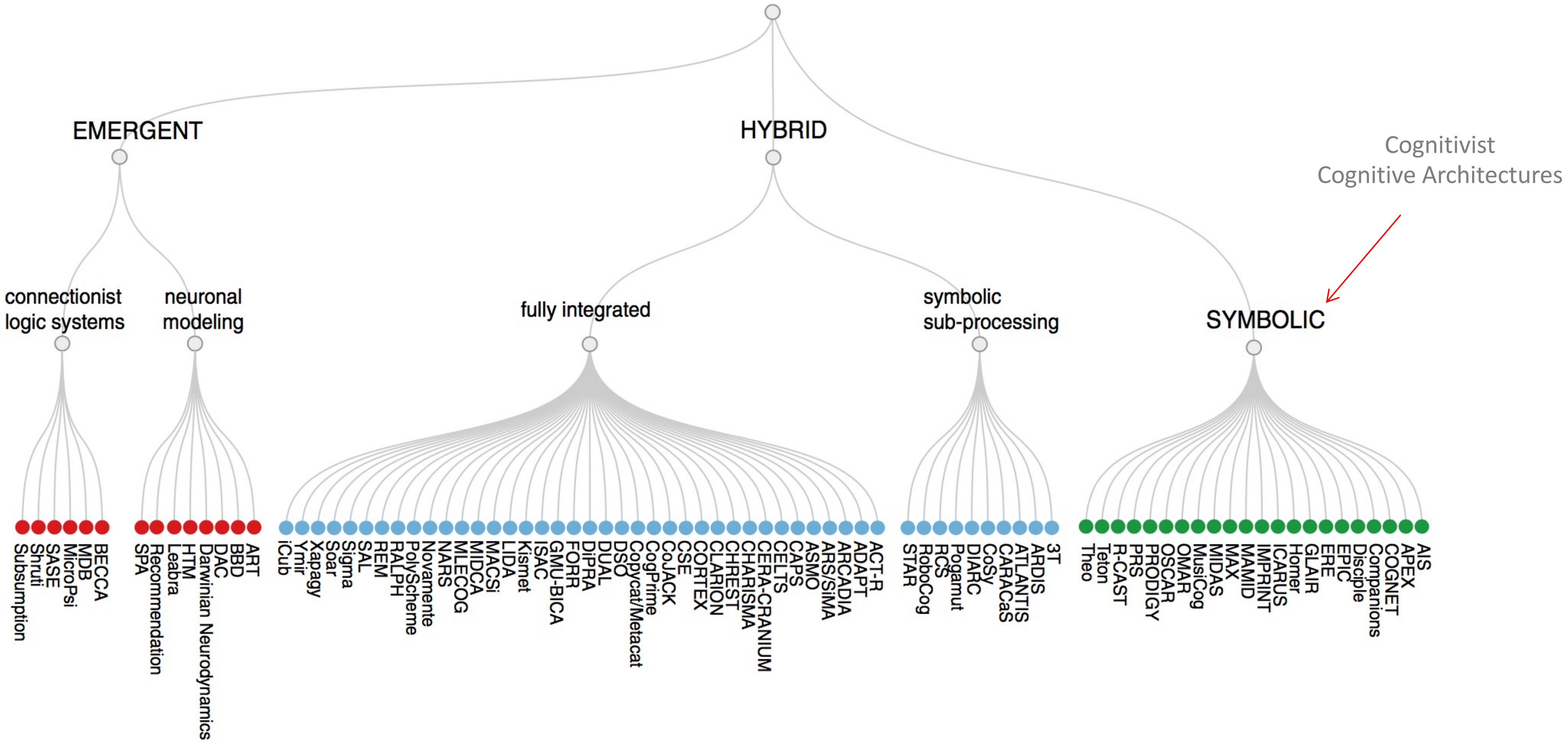
A Survey of Cognitive and Agent Architectures, University of Michigan, http://ai.eecs.umich.edu/cogarch0/ (12 cognitive architectures)

W. Duch, R. J. Oentaryo, and M. Pasquier. “Cognitive Architectures: Where do we go from here?”, Proc. Conf. Artificial General Intelligence, 122-136, 2008. (17 cognitive architectures)

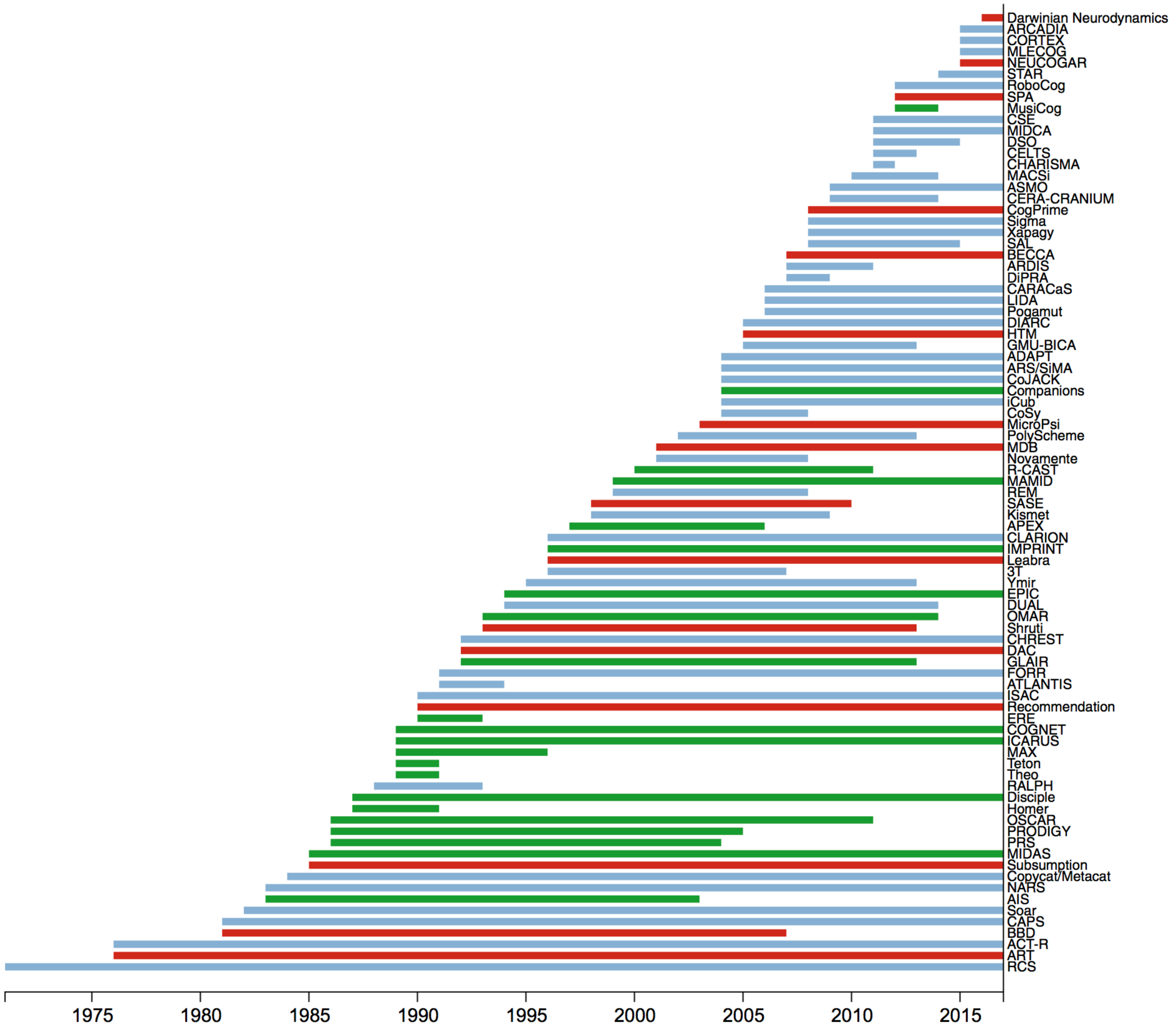
D. Vernon, G. Metta, and G. Sandini, "A Survey of Artificial Cognitive Systems: Implications for the Autonomous Development of Mental Capabilities in Computational Agents", IEEE Transactions on Evolutionary Computation, Vol. 11, No. 2, pp. 151-180, 2007. (14 cognitive architectures)

D. Vernon, C. von Hofsten, and L. Fadiga. "A Roadmap for Cognitive Development in Humanoid Robots", Cognitive Systems Monographs (COSMOS), Vol. 11, Springer, 2011. Chapter 5 and Appendix I (20 cognitive architectures)

I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, Vol. 53, No. 1, pp. 17-94, 2020. (84 cognitive architectures)



I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, Vol. 53, No. 1, pp. 17-94, 2020.



I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, Vol. 53, No. 1, pp. 17-94, 2020.

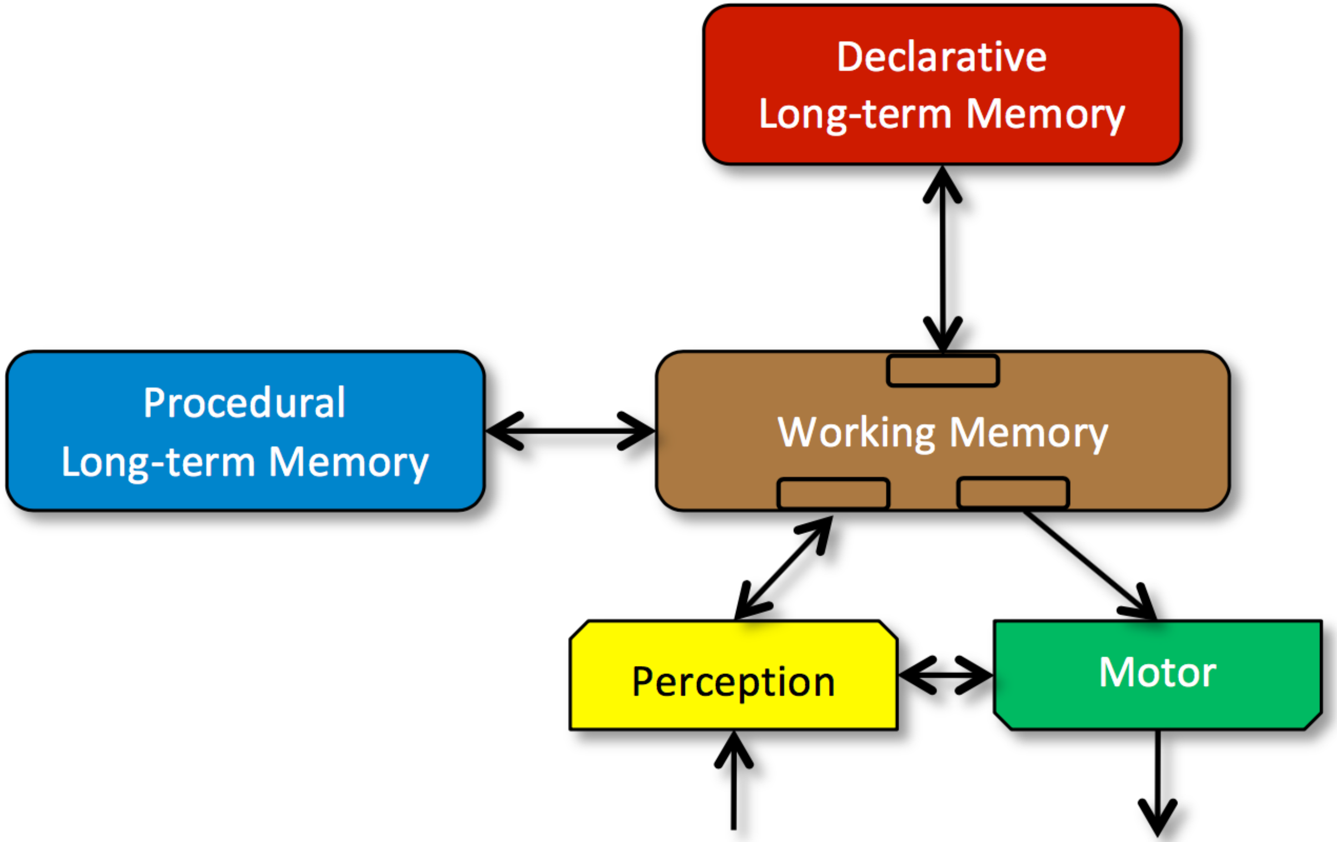
Core Cognitive Abilities

1. Perception
2. Attention
3. Action selection
4. Memory
5. Learning
6. Reasoning
7. Meta-cognition
8. Prospection

I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, Vol. 53, No. 1, pp. 17-94, 2020.

Not included in [Kotseruba and Tsotsos 2020]

A Standard Model of the Mind



A Standard Model of the Mind

Laird, J. E., Lebiere, C., Rosenbloom, P. S. A standard model of the mind: Toward a common computational framework across artificial intelligence, cognitive science, neuroscience, and robotics. AI Magazine 38 (4):13–26, 2017.

Rosenbloom, P. S., Laird, J. E., and Lebiere, C. Précis of a 'Standard Model of the Mind', Advances in Cognitive Systems, Vol. 5, pp. 1-4, 2017.

Stocco, A., Laird, J., Lebiere, C., and Rosenbloom, R. Empirical evidence from neuroimaging data for a standard model of the mind. In: Kalish, C., Rau, M., Zhou, J., Rogers, T. T. (eds) Proceedings of the 40th Annual Meeting of the Cognitive Science Society, pp. 1094–1099, 2018.

A Common Model of Cognition

AAAI 2018 Fall Symposium on
A Common Model of Cognition
October 18-20, Westin Arlington Gateway
Arlington, Virginia

Home
Organizing Committee
Call for Participation
Registration
Schedule
2017 AAAI Fall Symposium on a 'Standard Model of the Mind'
2017 Schedule and Slides

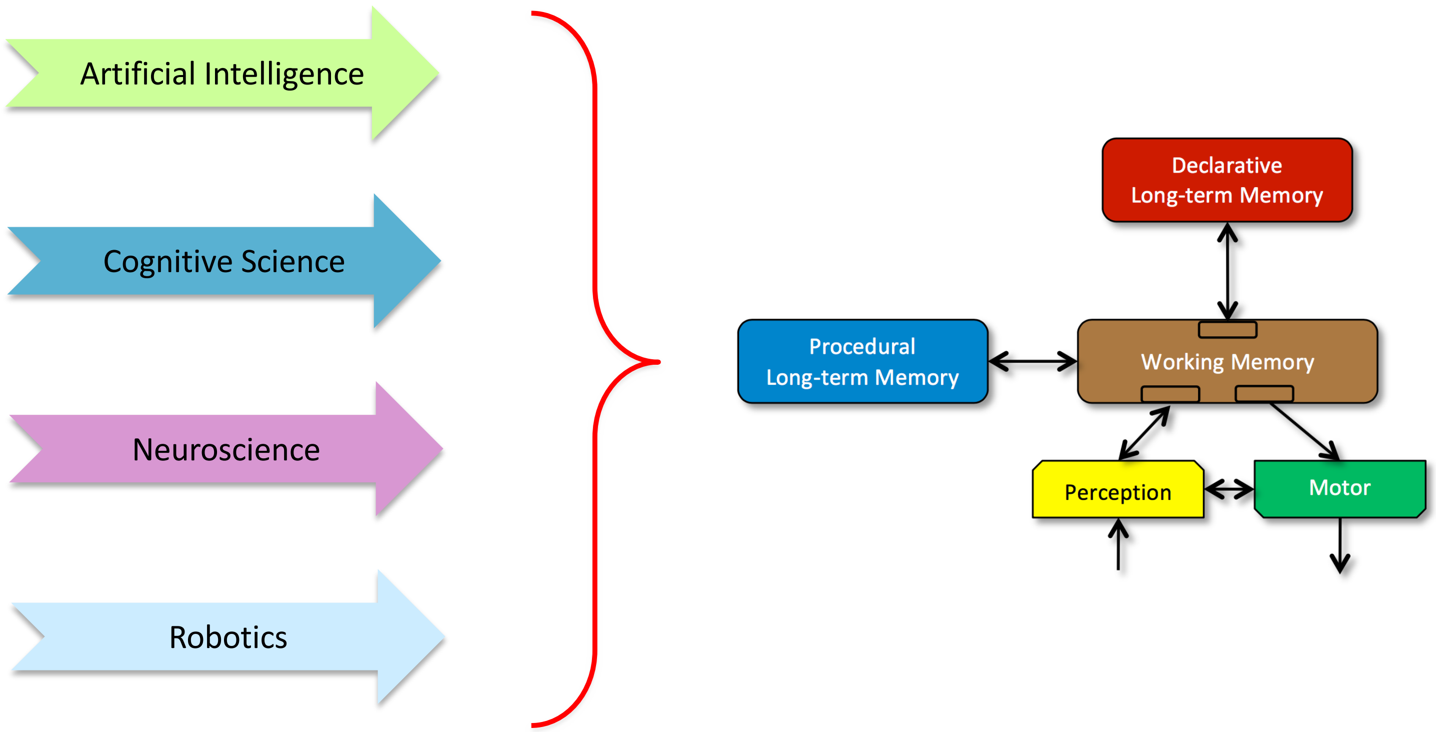
2018 AAAI Fall Symposium on 'A Common Model of the Cognition'

A mind is a functional entity that can think, and thus support intelligent behavior. Artificial intelligence, cognitive science, neuroscience, and robotics all contribute to our understanding of minds, although each draws from a different perspective. Artificial intelligence concerns building artificial minds, and thus cares most about how systems can be built that exhibit intelligent behavior. Cognitive science concerns modeling natural minds, and thus cares most about understanding cognitive processes that yield human thought. Neuroscience concerns the structure and function of brains, and thus cares most about how brains induce minds. Robotics concerns building and directing artificial bodies, and thus cares most about how minds control such bodies.

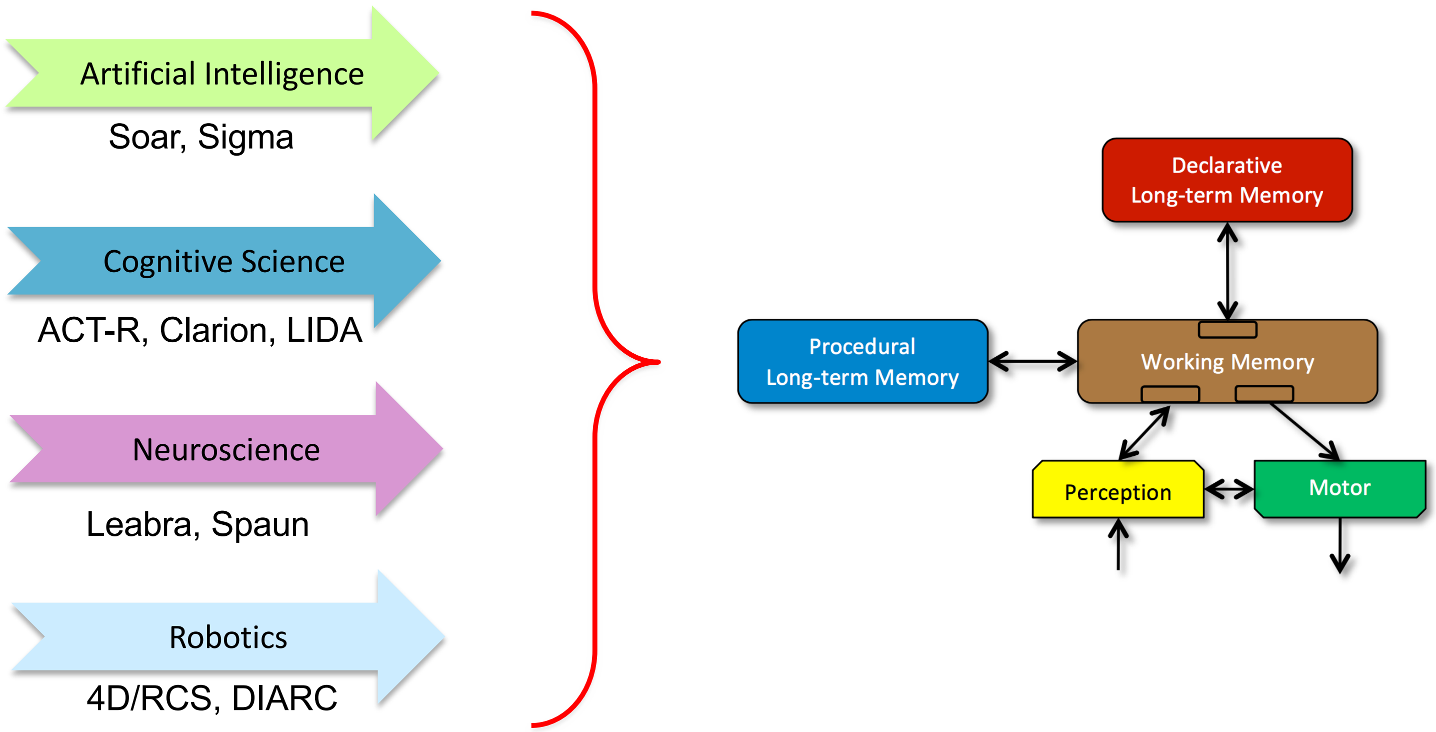
Will research across these disciplines ultimately converge on a single understanding of mind? This is a deep scientific question to which there is as yet no answer. However, there must at least be a single answer for cognitive science and neuroscience, as they both investigate the same mind, or narrow class of minds, albeit at different levels of abstraction. Research that is inspired by natural systems also may fit within this class of minds, particularly if it is slightly abstracted; but so too may research that has no such aspiration yet still finds itself in the same neighborhood for functional reasons. This broader class comprises what can be called human-like minds.

Our goal with this symposium is to engage the international research community in developing *A Common Model of Cognition;* that is, a community consensus concerning the mental structures and process implicated in human-like minds to the extent that such a consensus exists. The intent, at least for the foreseeable future, is not to develop a single implementation or model of cognition by which everyone concerned with human-like cognition would abide, or even a theory in which all of the details are agreed to as correct. What is sought though is a statement of the best consensus given the community's current understanding of cognition, plus a sound basis for further refinement as more is

A Common Model of Cognition



A Common Model of Cognition



A Common Model of Cognition

- cf. Standard Model in particle physics:
- For human-like minds
  - cumulative reference point … combines what is known
  - focus efforts to extend or revise
  - Not intended to be complete theory / model / implementation
  - Omissions: statement that a consensus is needed

A Common Model of Cognition

Hypothesis

"Cognitive architectures provide the appropriate computational abstraction for defining a standard model"

Standard model is not itself a cognitive architecture

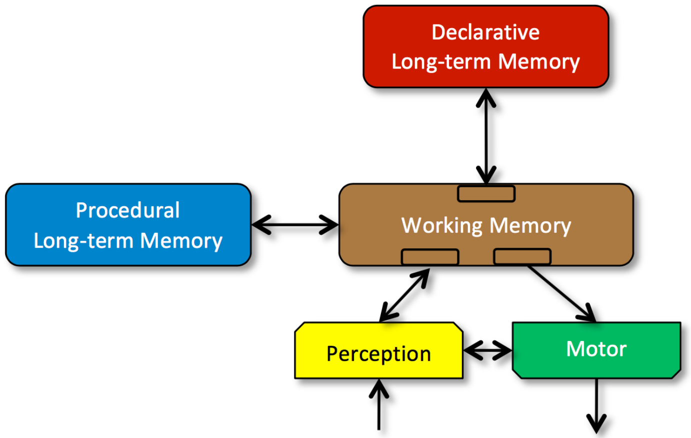
A Common Model of Cognition

- Evaluate single components
- Evaluate combinations of components
- Make components openly available to the research community
- Facilitate standard tests / testbeds

A Common Model of Cognition

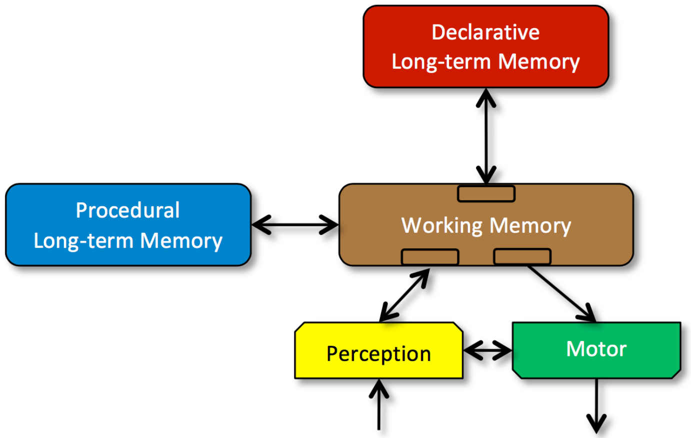
Key aspects

- Structure and processing
- Memory and content
- Learning
- Perception
- Motor (action)



Motor

- Converts the symbol structures & metadata into external action
- Controlling body effectors
- ”No consensus as the the form this should take in the standard model”



A Common Model of Cognition

"The standard model … remains incomplete …

[and] is silent, for example, concerning

meta-cognition

emotion

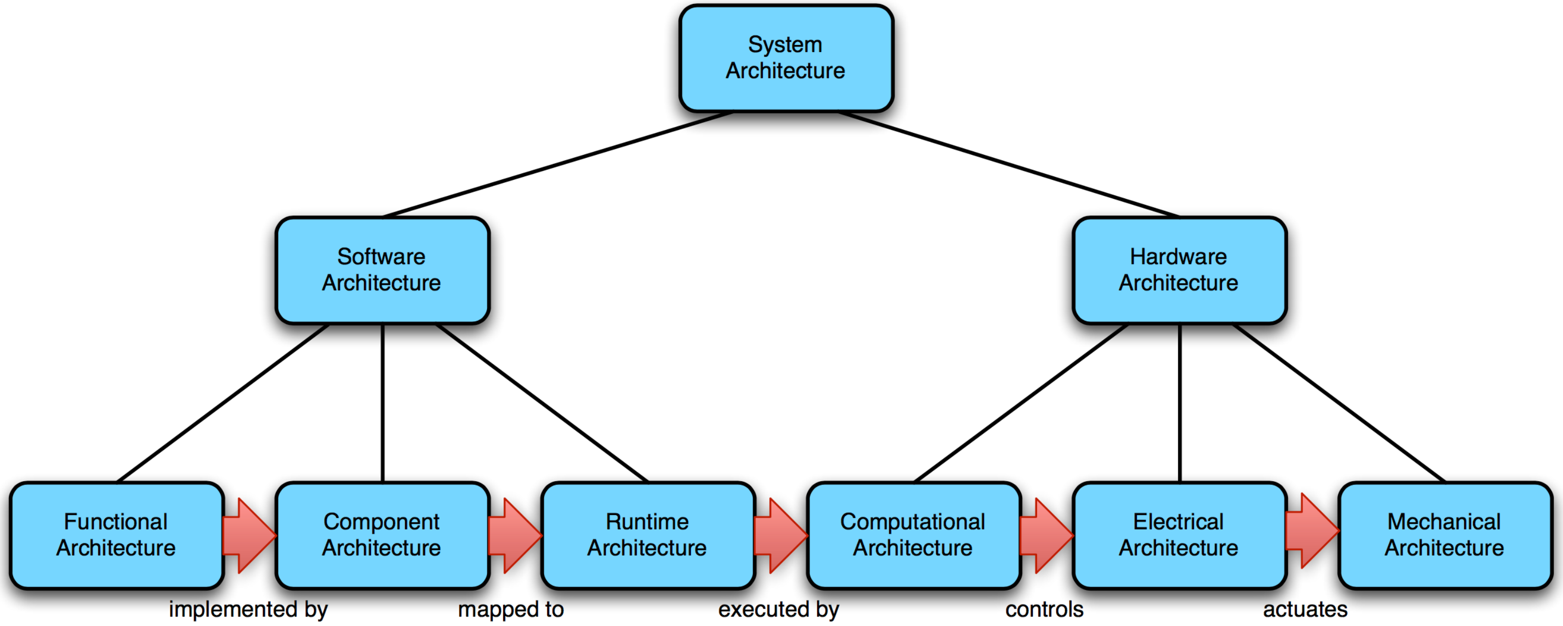
mental imagery

direct communication and learning across modules,

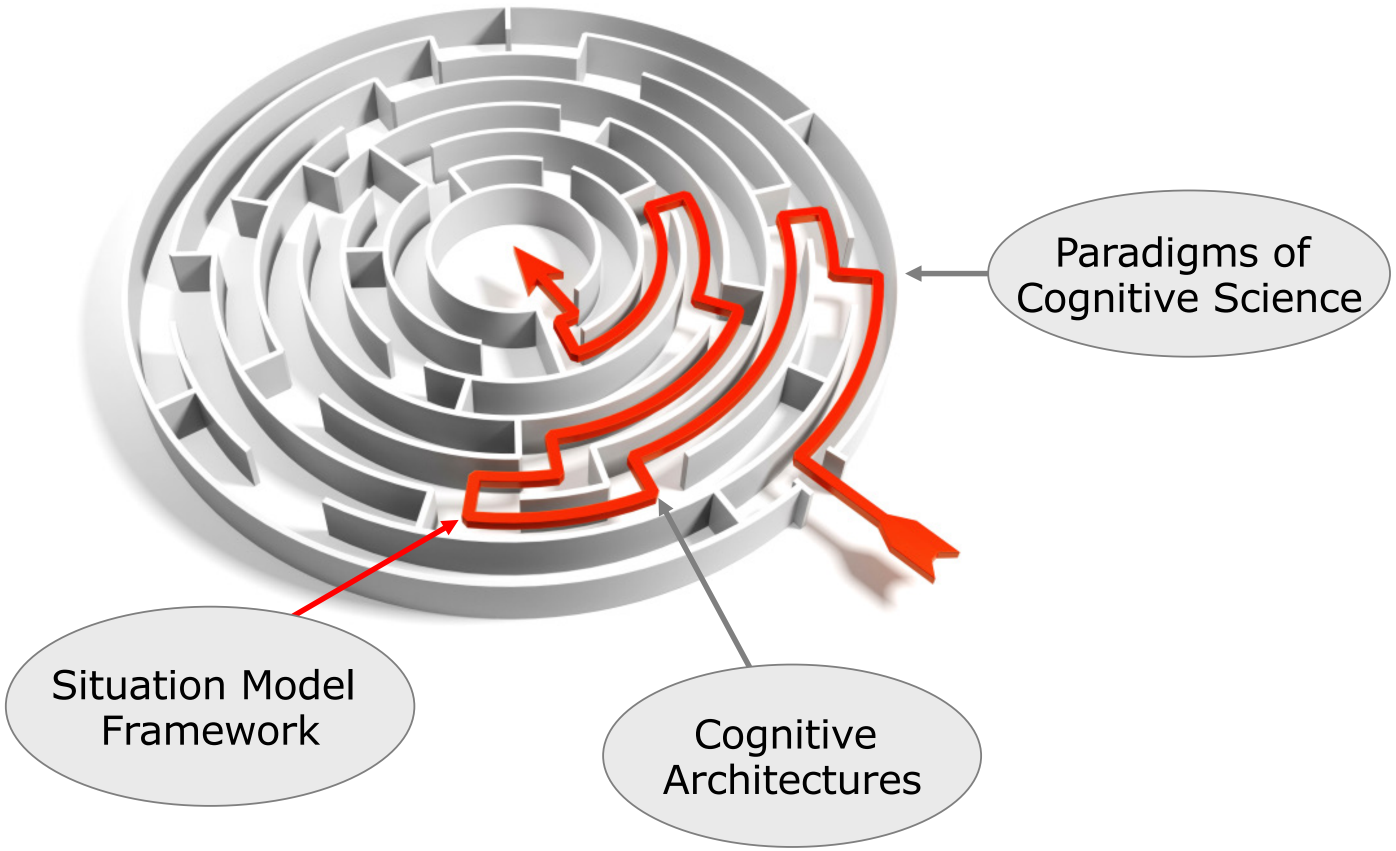
the distinction between semantic and episodic memory

and mechanisms necessary for social cognition"

Operational Cognitive Architectures



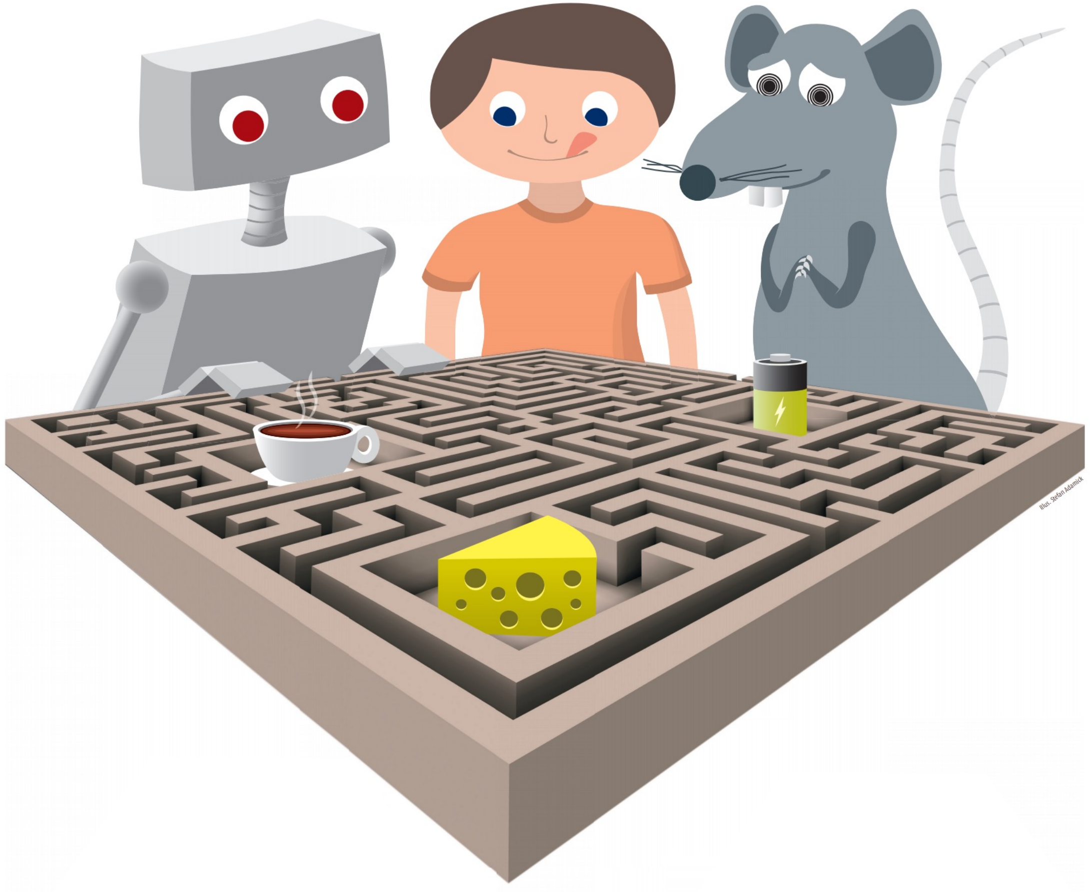
G. Kraetzschmar, Software Engineering Factors for Cognitive Robotics, RockEU2 Robotics Coordination Action for Europe Two, Deliverable 3.5, 2017.
https://www.eu-robotics.net/eurobotics/about/projects/rockeu2.html



Paradigms of Cognitive Science
Situation Model Framework
Cognitive Architectures

The ZiF Research Group on

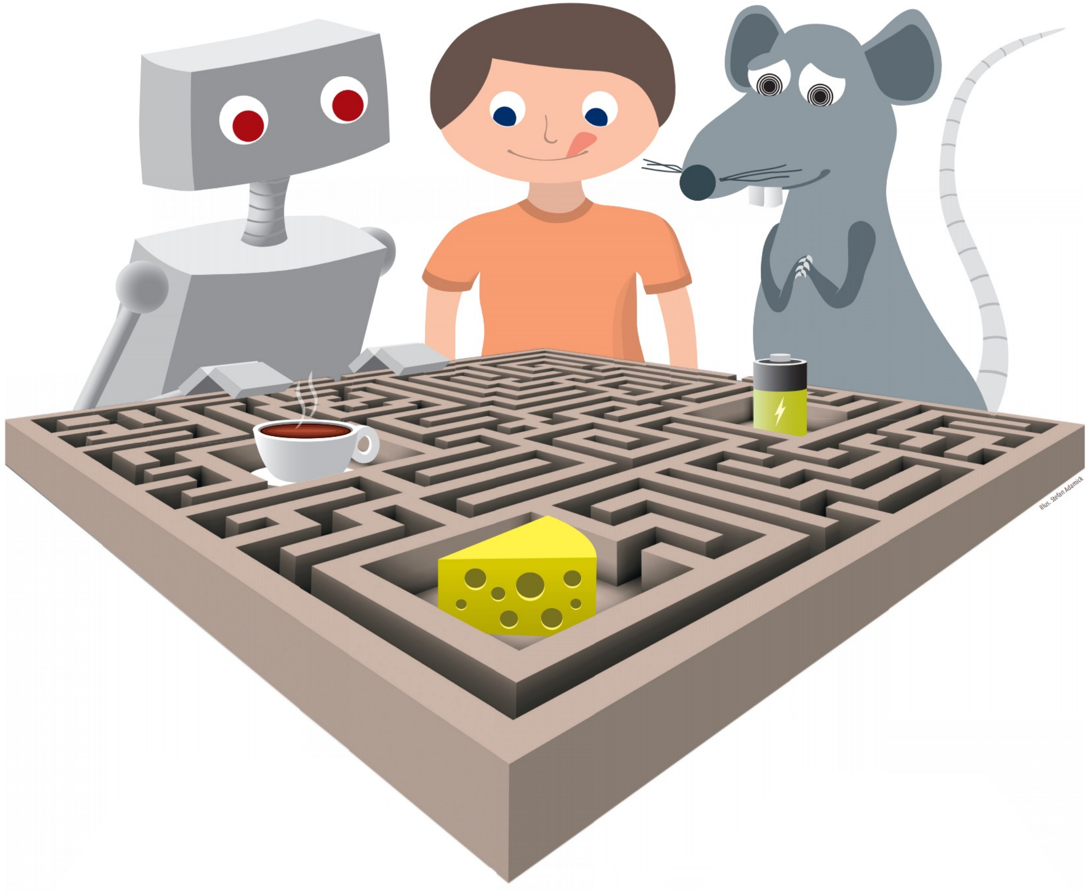
Cognitive behavior of humans, animals, and machines: Situation model perspectives



The ZiF Research Group on

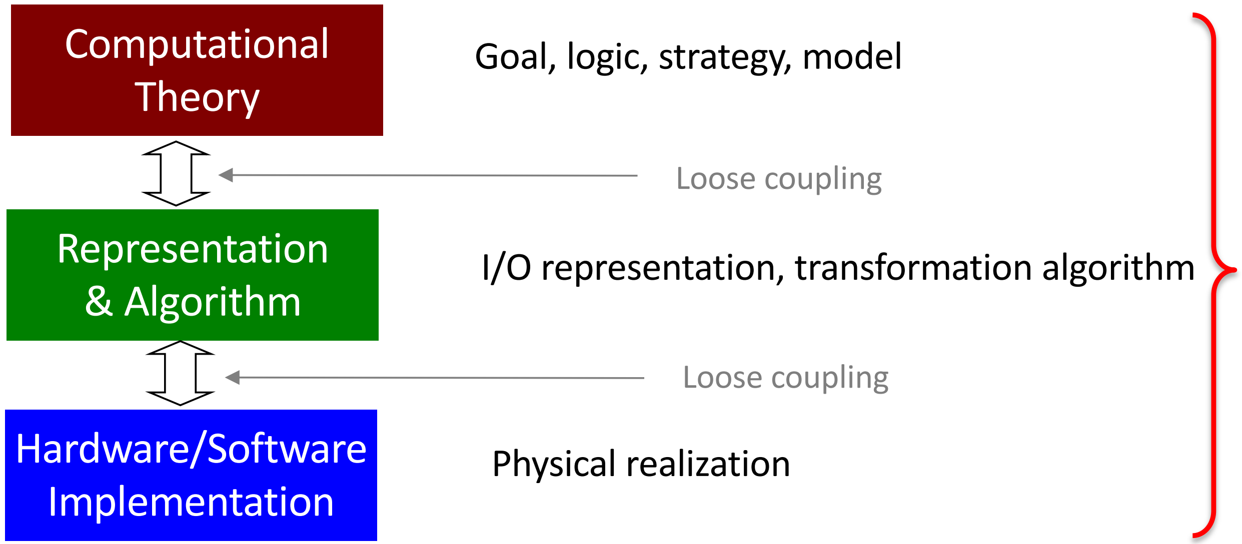
Cognitive behavior of humans, animals, and machines: Situation model perspectives

Flexible
Context-sensitive
Behaviour



Marr’s Hierarchy of Abstraction

(aka The Levels of Understanding Framework)



Situation Model Framework

All three levels of abstraction

Does not yet commit to a specific computational model, representation, or algorithm

D. Marr and T. Poggio. "From understanding computation to understanding neural circuitry", in E. Poppel, R. Held, and J. E. Dowling, editors, Neuronal Mechanisms in Visual Perception, volume 15 of Neurosciences Research Program Bulletin, pages 470–488. 1977.

D. Marr. Vision. Freeman, San Francisco, 1982.

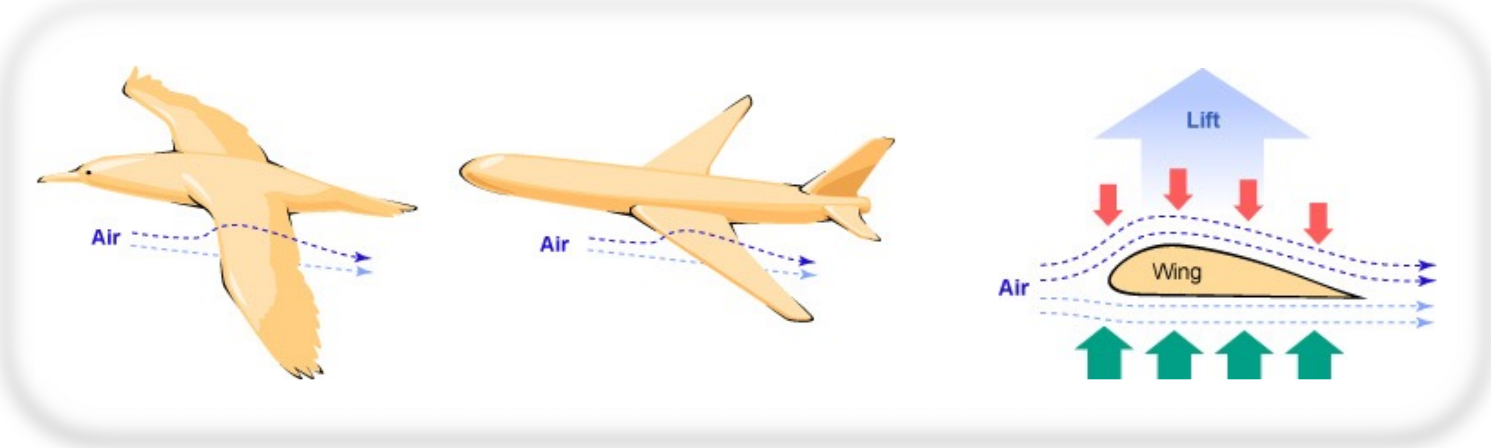
T. Poggio. The levels of understanding framework, revised. Perception, 41:1017–1023, 2012.

Marr’s Hierarchy of Abstraction

(aka The Levels of Understanding Framework)

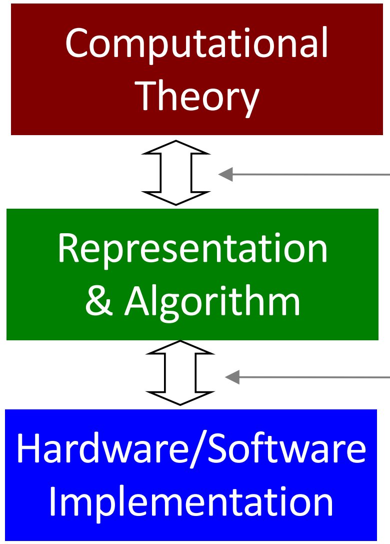
“Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers: it just cannot be done.
In order to understand bird flight, we have to understand aerodynamics;
only then do the structure of feathers and the different shapes of birds’ wings make sense”

Marr, D. *Vision*, Freeman, 1982.



Marr's Hierarchy of Abstraction

(aka The Levels of Understanding Framework)



Goal, logic, strategy, model

Loose coupling

I/O representation, transformation algorithm

Loose coupling

Physical realization

Situation Model Framework

Addresses all three levels of abstraction

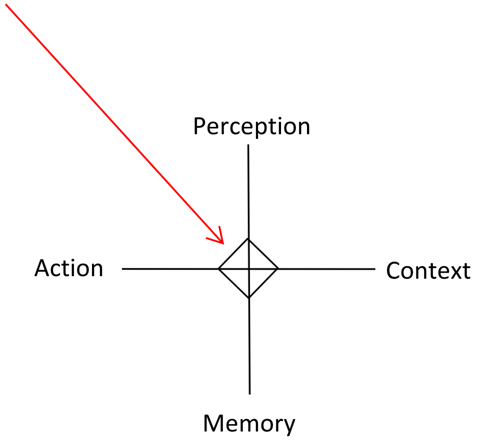
Does not yet commit to a specific computational model, representation, or algorithm

The goal of the Situation Model Framework is to set out in explicit terms the assumptions – foundations – on which to build such a theory

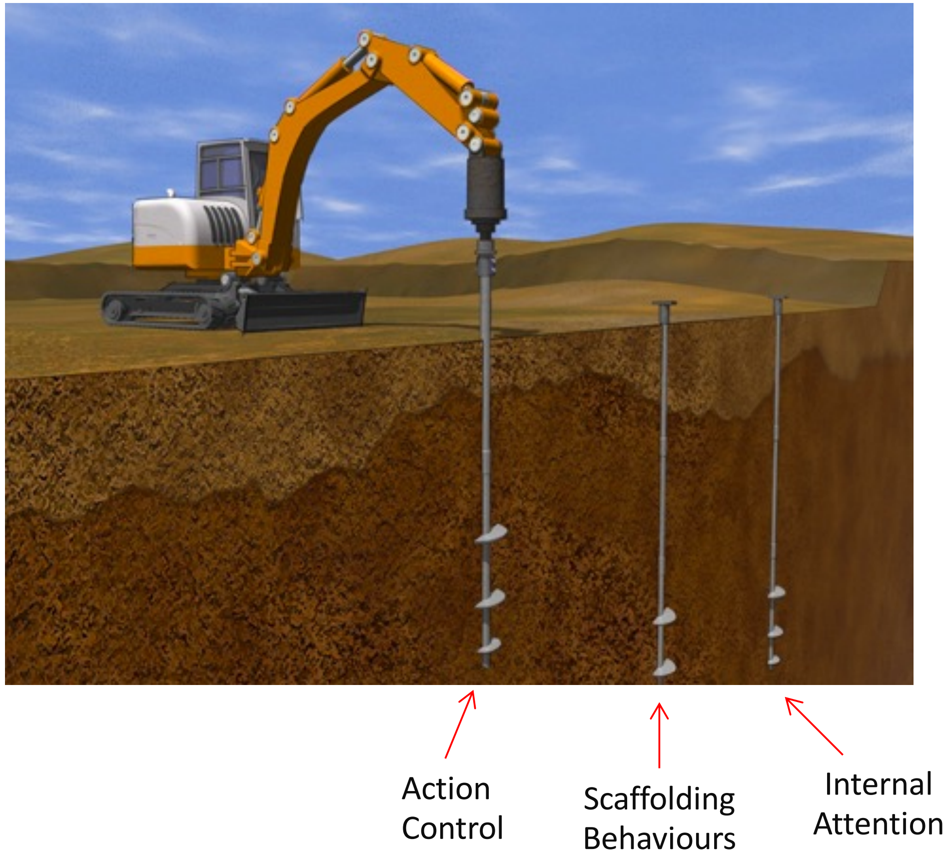
Situation Model Framework

Three Foundational Themes:

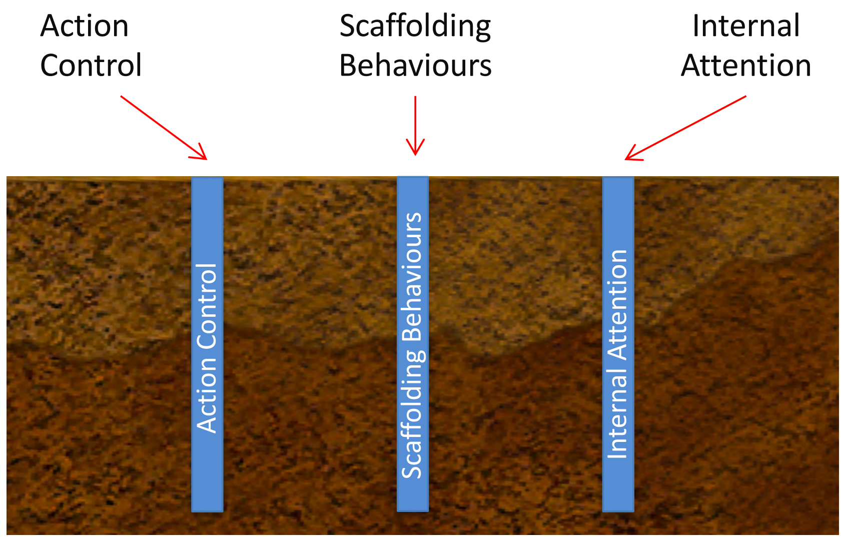
1. Control of action: integrative process in cognition
2. Complex behaviours emerge by scaffolding simpler behaviours
3. Internal Attention is a prioritizing control mechanism:



https://www.aboutcivil.org/pile-foundations-design-construction.html



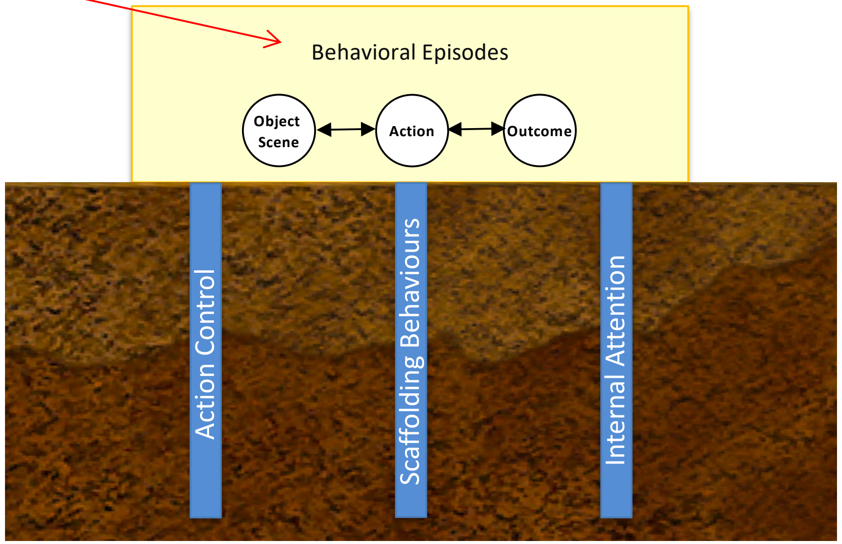
Situation Model Framework



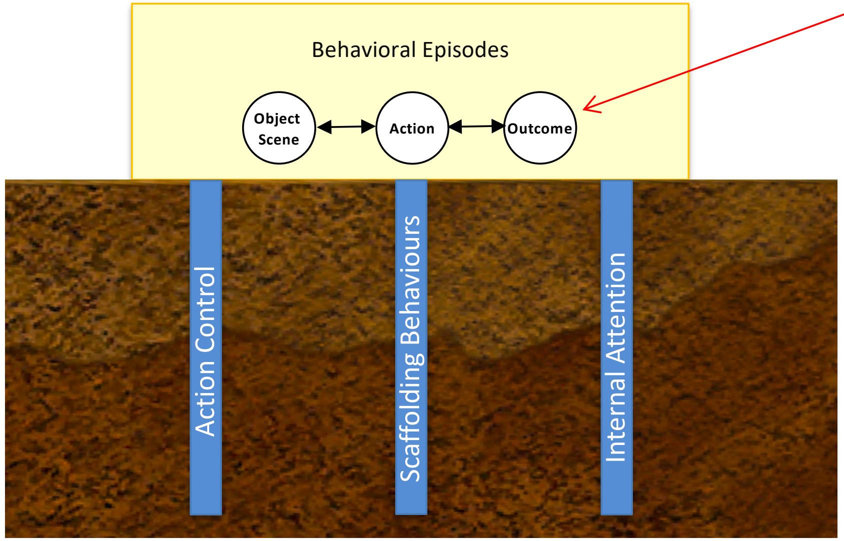
Situation Model Framework

Joint perception-action representation

Abstract representation:
unencumbered by low-level
sensorimotor information



Situation Model Framework

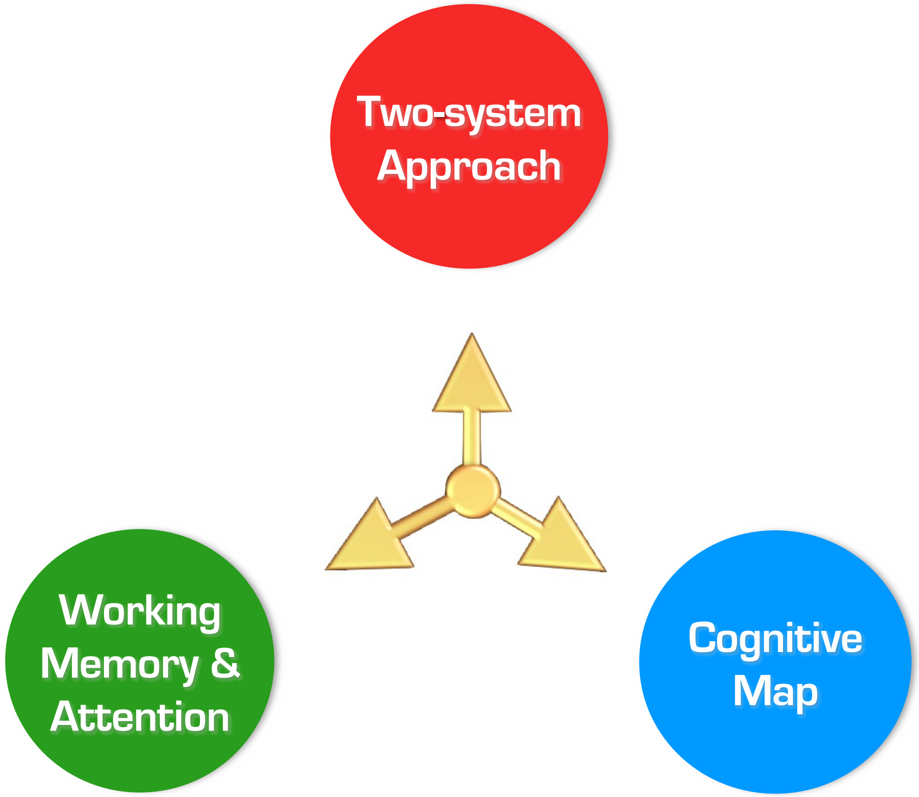


"Intended Behavioural Outcome"
(cf. goal-directed nature of actions)

Perception of the action outcome

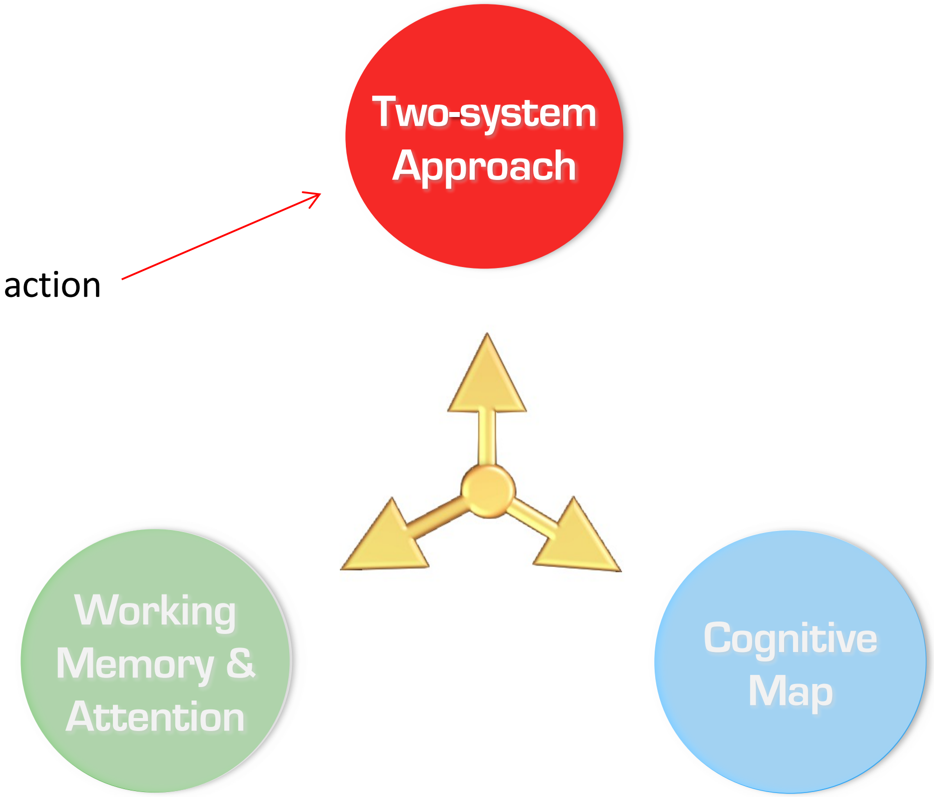
Captures both spatial and temporal aspects

Situation Model Framework



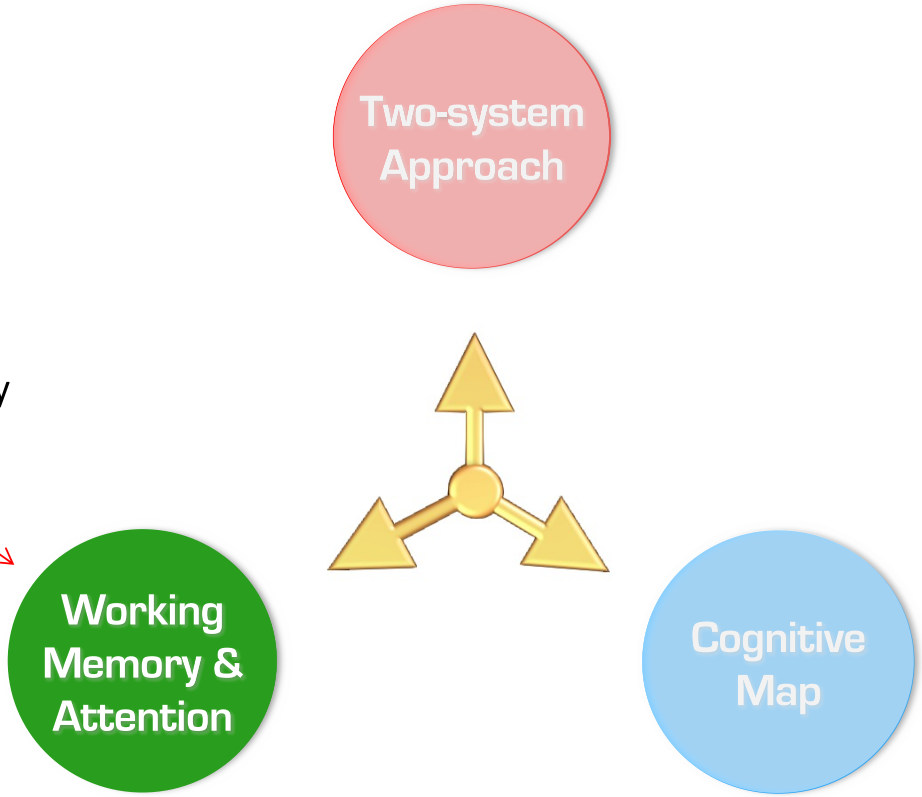
Situation Model Framework

Two-system approach to thought and action

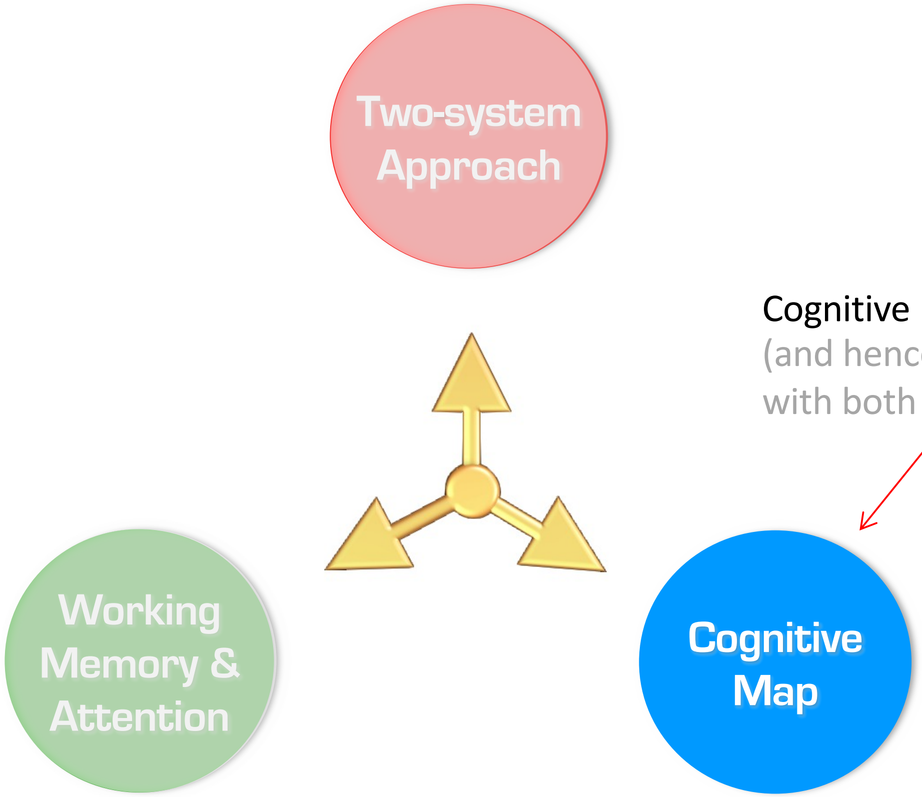


Situation Model Framework

Capacity limitation of working memory
& attentional control



Situation Model Framework



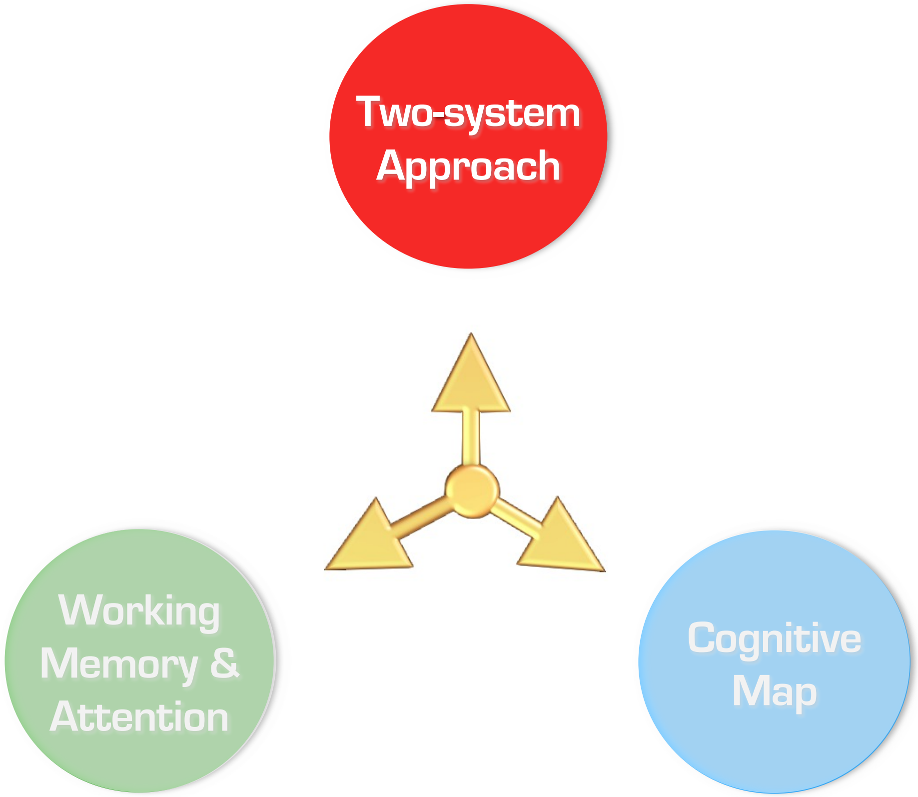
Cognitive map: extended form of behavioural episode
(and hence joint action-perception representation with both spatial and temporal characteristics)

Situation Model Framework

Two classes of behaviour:

1. Routine habitual
   ... handled by system 1

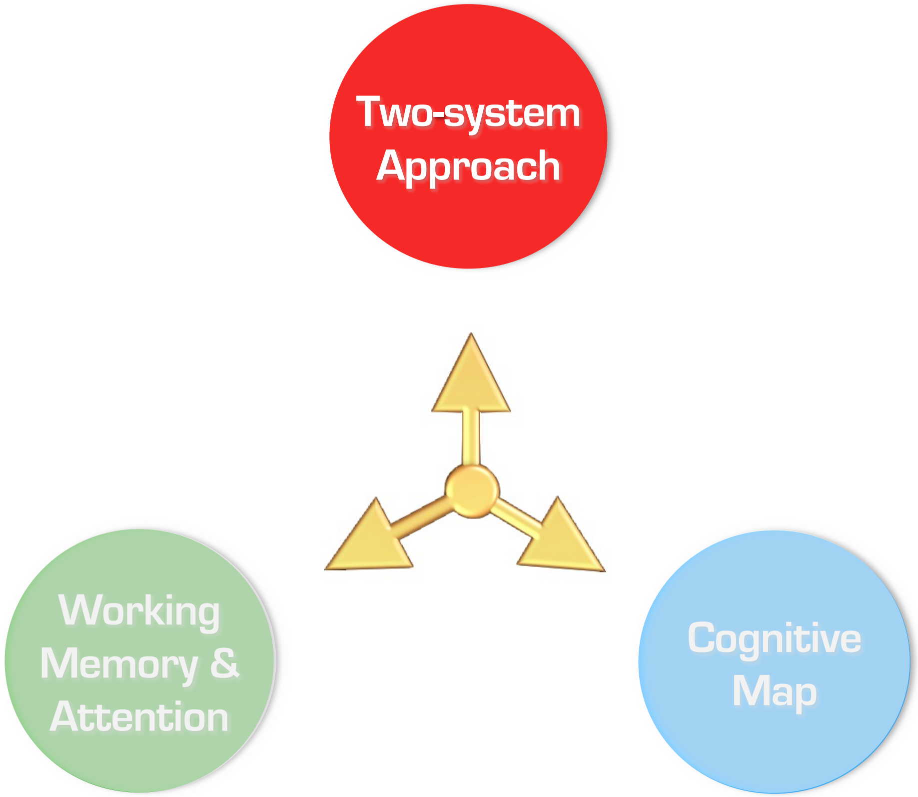
2. Actions requiring deliberation
   ... handled by system 2



Situation Model Framework

System 1

- Retrieves n behaviour episodes
- Winner-take-all competition
- Executes the winner



Situation Model Framework

System 1

- Retrieves n behaviour episodes

- Winner-take-all competition

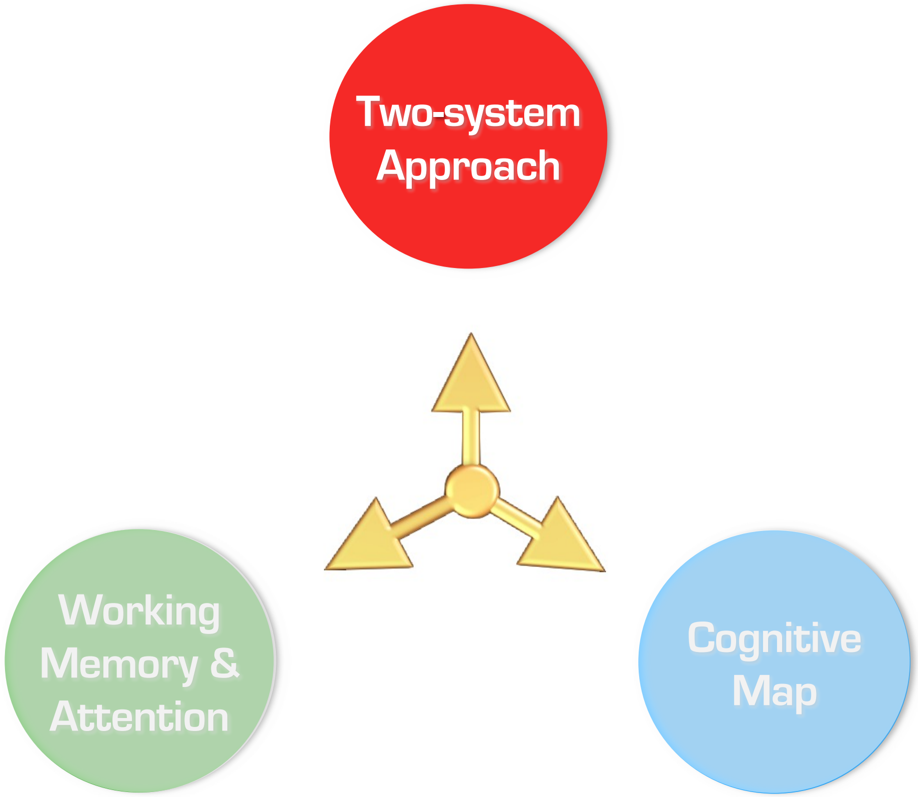
- Executes the winner

But ...

Behavioural episodes are abstract

So ...

Sensor and motor information
is resolved in real-time.



Situation Model Framework

System 1

- Retrieves n behaviour episodes

- Winner-take-all competition

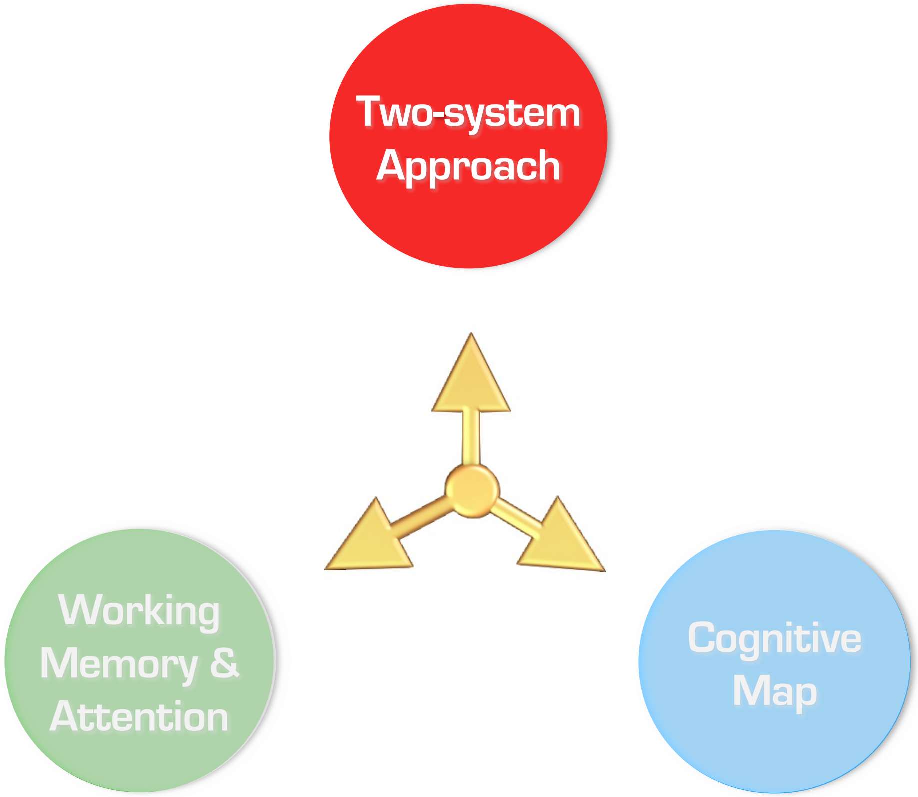
- Executes the winner

But ...

Behavioural episodes are abstract

So ...

Sensor and motor information
is resolved in real-time.



System 2

Has additional mechanisms to

- Construct novel episodes

- Predict outcome using
  internal simulation
  (or enact in reality)

- Refine

- Assimilate in LTM

Situation Model Framework

System 1

- Retrieves n behaviour episodes

- Winner-take-all competition

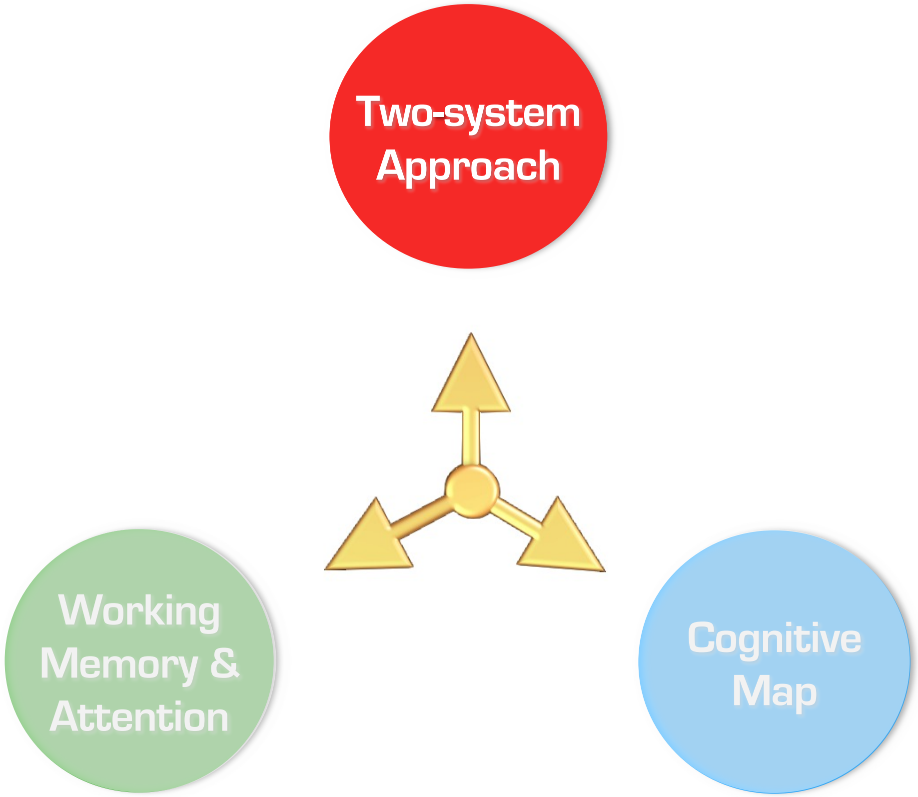
- Executes the winner

But ...

Behavioural episodes are abstract

So ...

Sensor and motor information
is resolved in real-time.



System 2

Has additional mechanisms
in **working memory** to

- Construct novel episodes

- Predict outcome using
  internal simulation
  (or enact in reality)

- Refine

- Assimilate in LTM

⇒ FLEXIBILITY

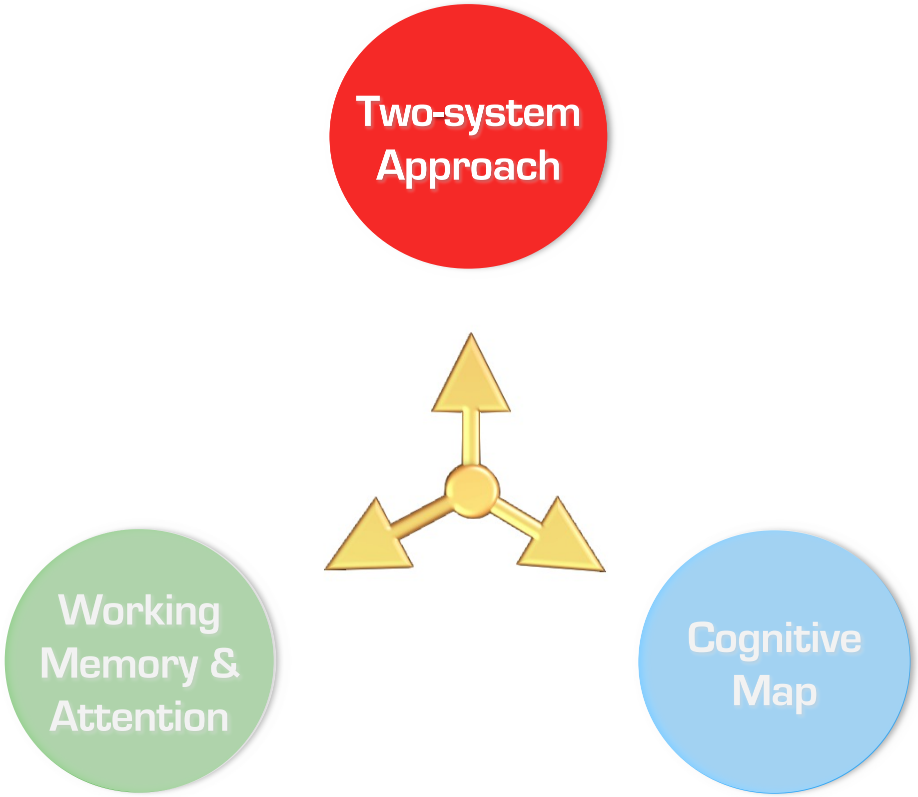
Situation Model Framework

System 1

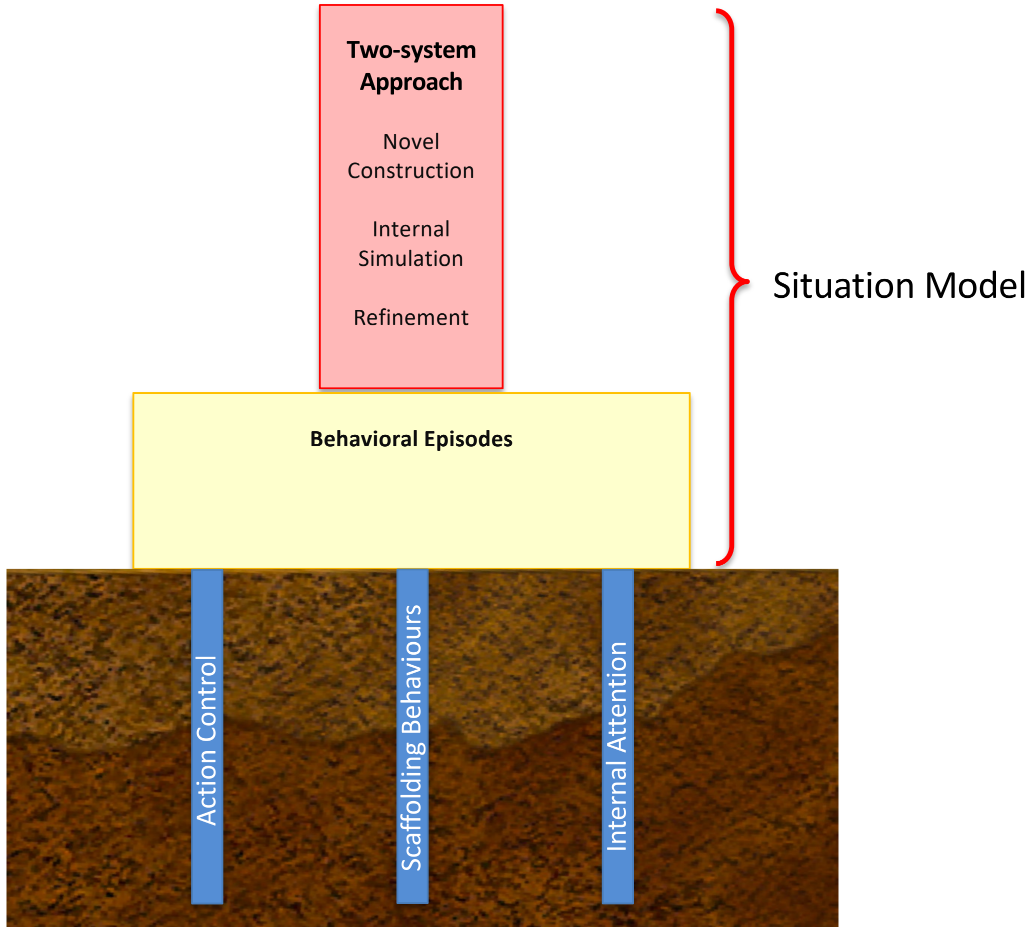
Reactive control of action

System 2

Prospective control of action

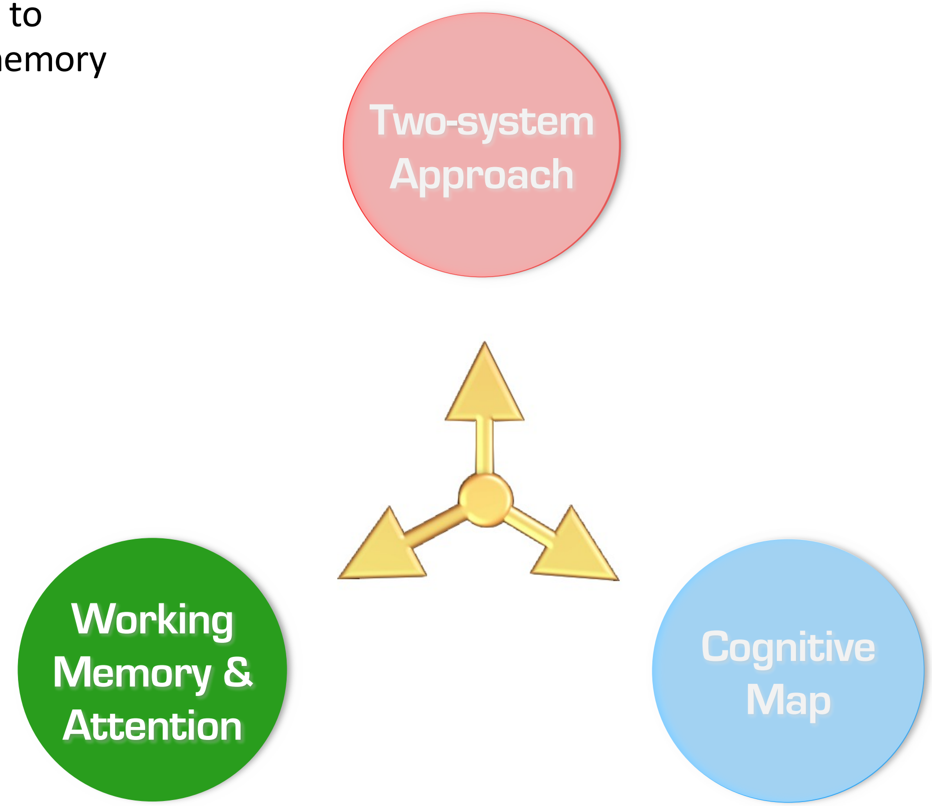


Situation Model Framework



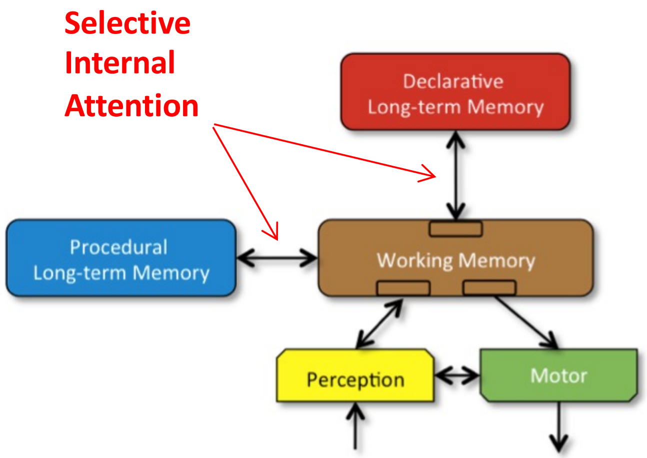
Situation Model Framework

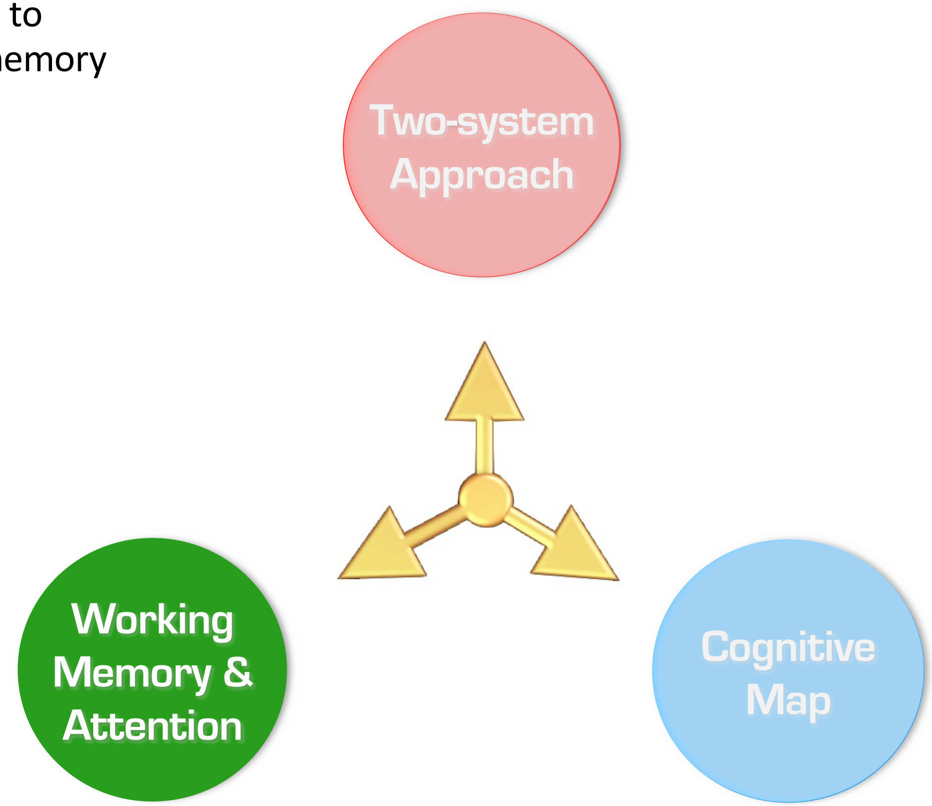
System 1 and 2 need efficient access to
behavioural episodes in long-term memory



Situation Model Framework

System 1 and 2 need efficient access to behavioural episodes in long-term memory



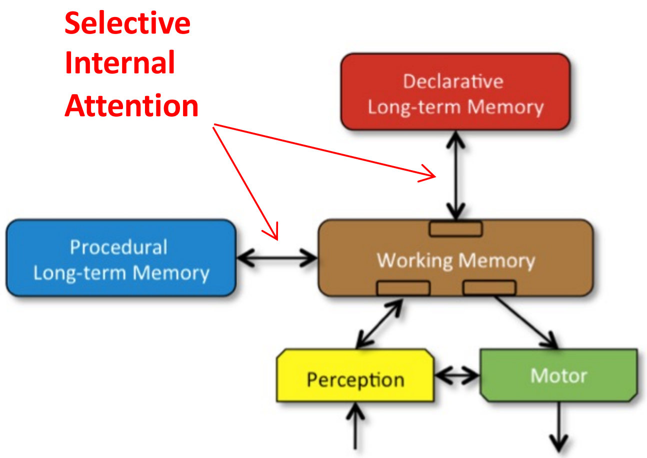


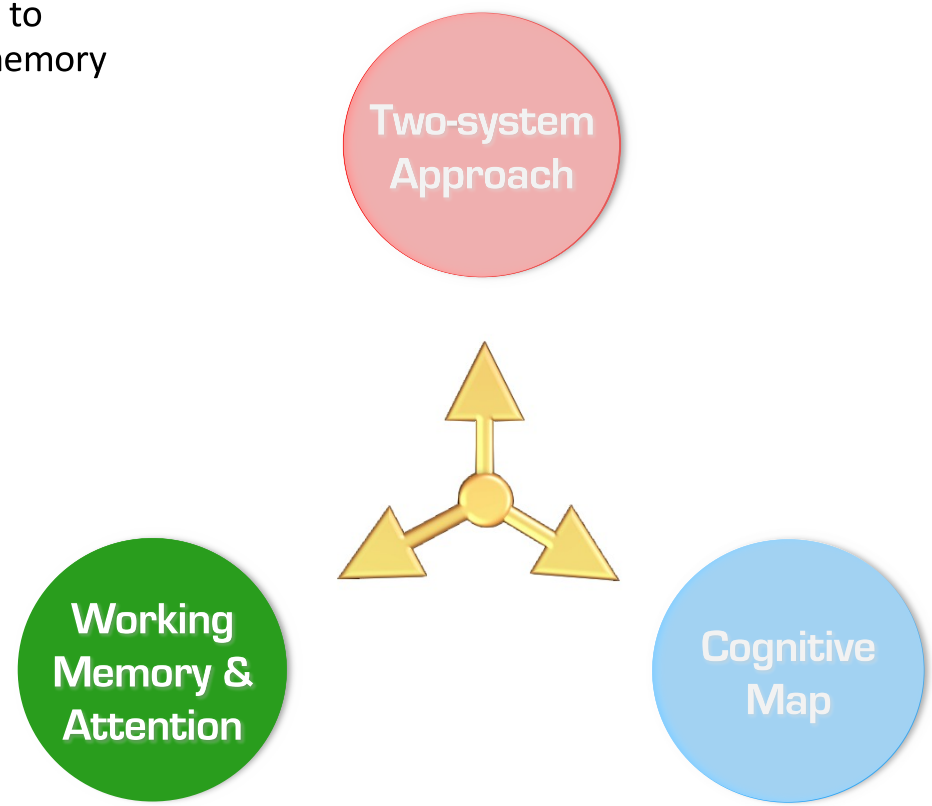
Laird, J. E., Lebiere, C. & Rosenbloom, P. S. . A Standard Model of the Mind: Toward a Common Computational Framework across Artificial Intelligence, Cognitive Science, Neuroscience, and Robotics. AI Magazine, 2017.

Situation Model Framework

System 1 and 2 need efficient access to behavioural episodes in long-term memory

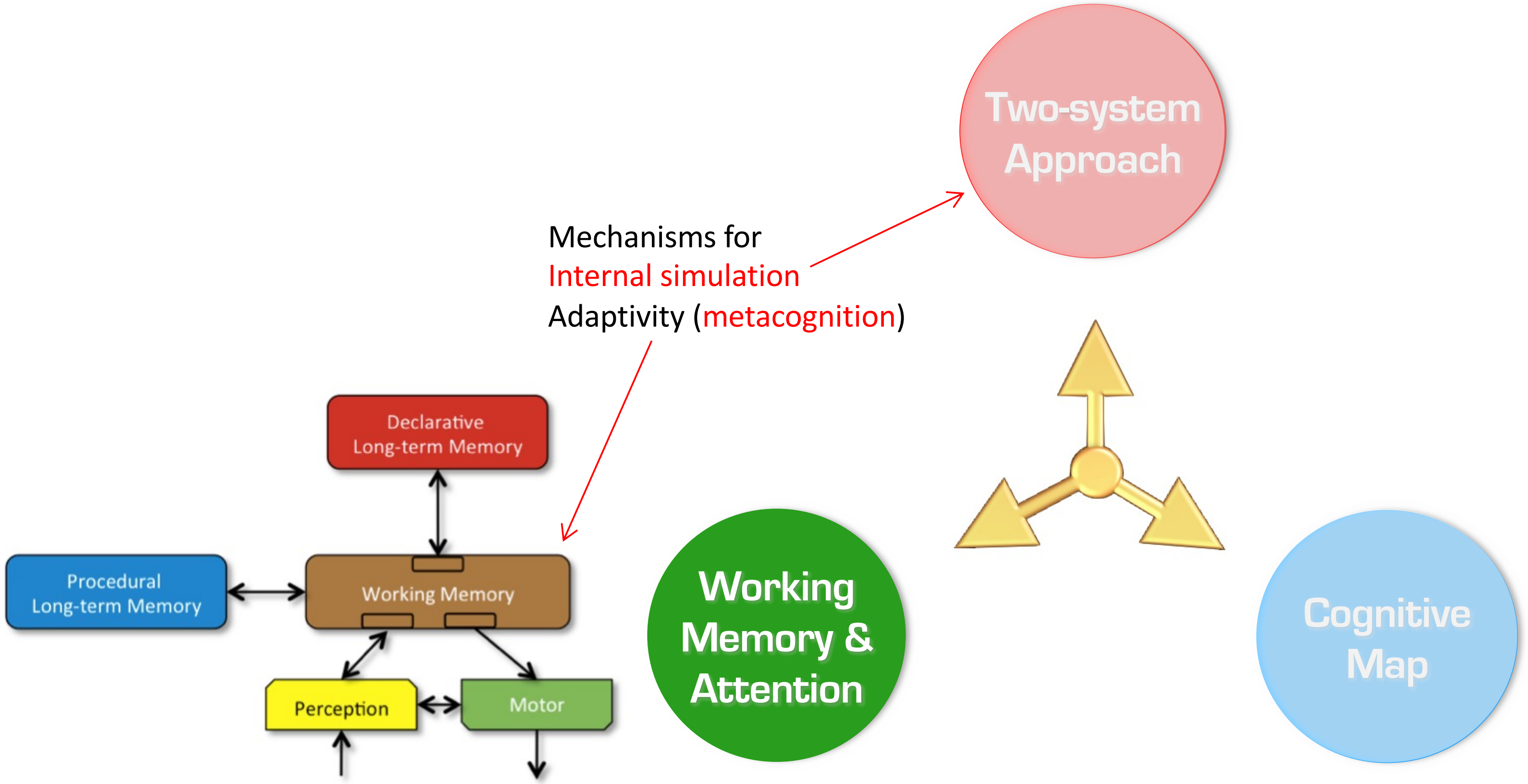
⇒ CONTEXT SENSITIVITY





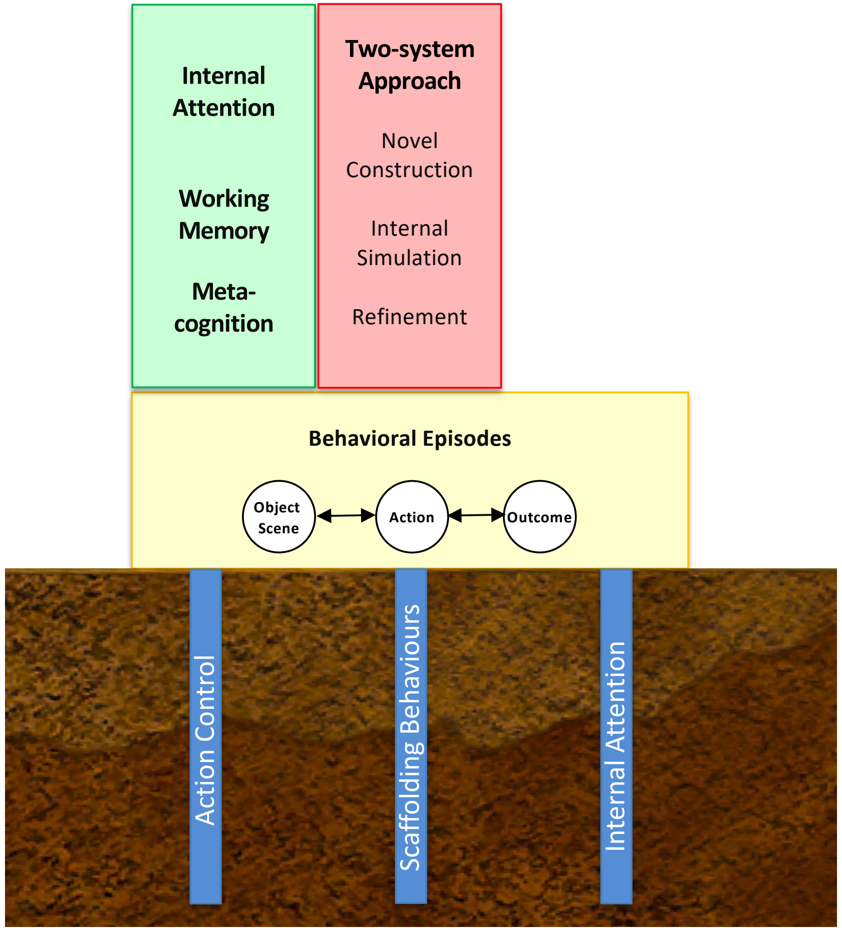
Laird, J. E., Lebiere, C. & Rosenbloom, P. S. . A Standard Model of the Mind: Toward a Common Computational Framework across Artificial Intelligence, Cognitive Science, Neuroscience, and Robotics. AI Magazine, 2017.

Situation Model Framework

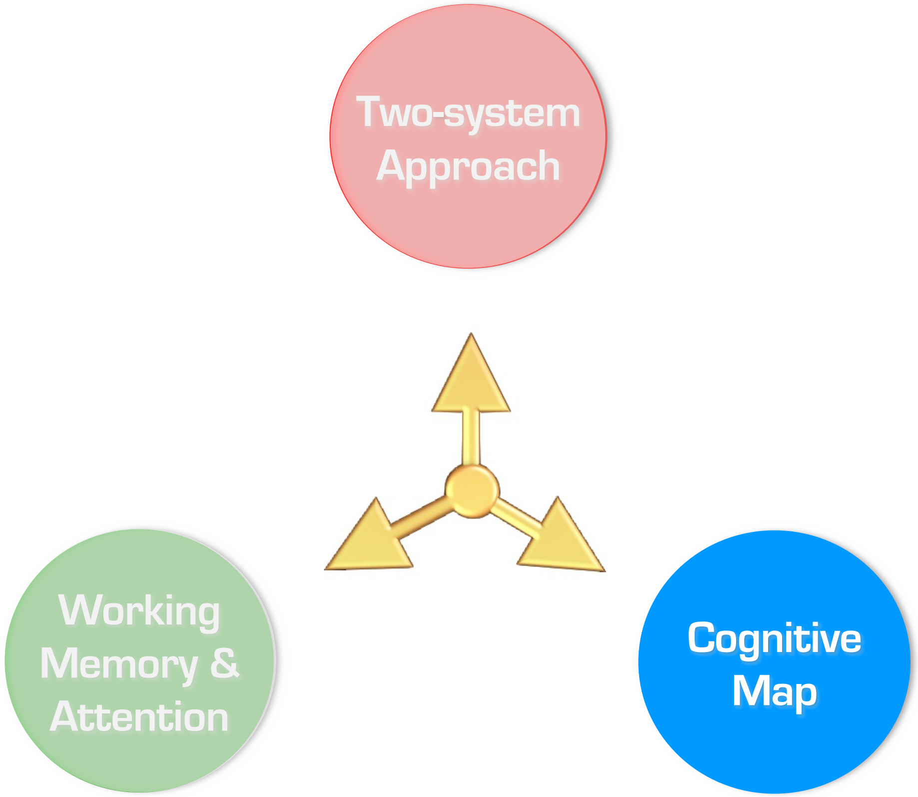


Laird, J. E., Lebiere, C. & Rosenbloom, P. S. . A Standard Model of the Mind: Toward a Common Computational Framework across Artificial Intelligence, Cognitive Science, Neuroscience, and Robotics. AI Magazine, 2017.

Situation Model Framework



Situation Model Framework

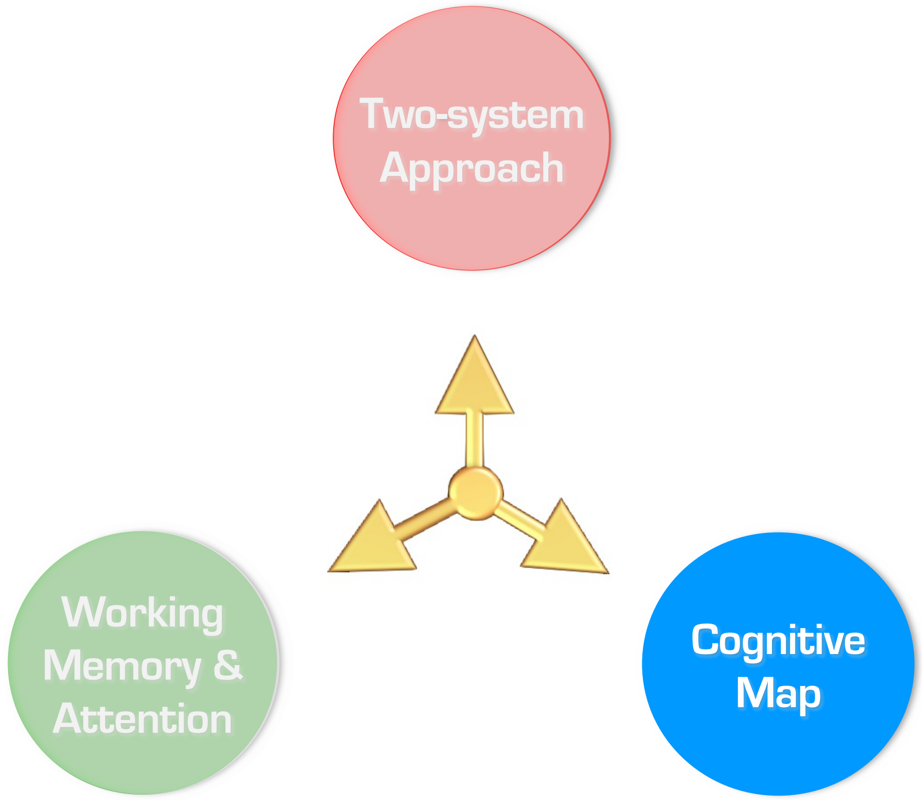


Extended form of behavioural episode:

- Joint perception-action spatio-temporal representation

- Causal link between scene, object, action, outcome

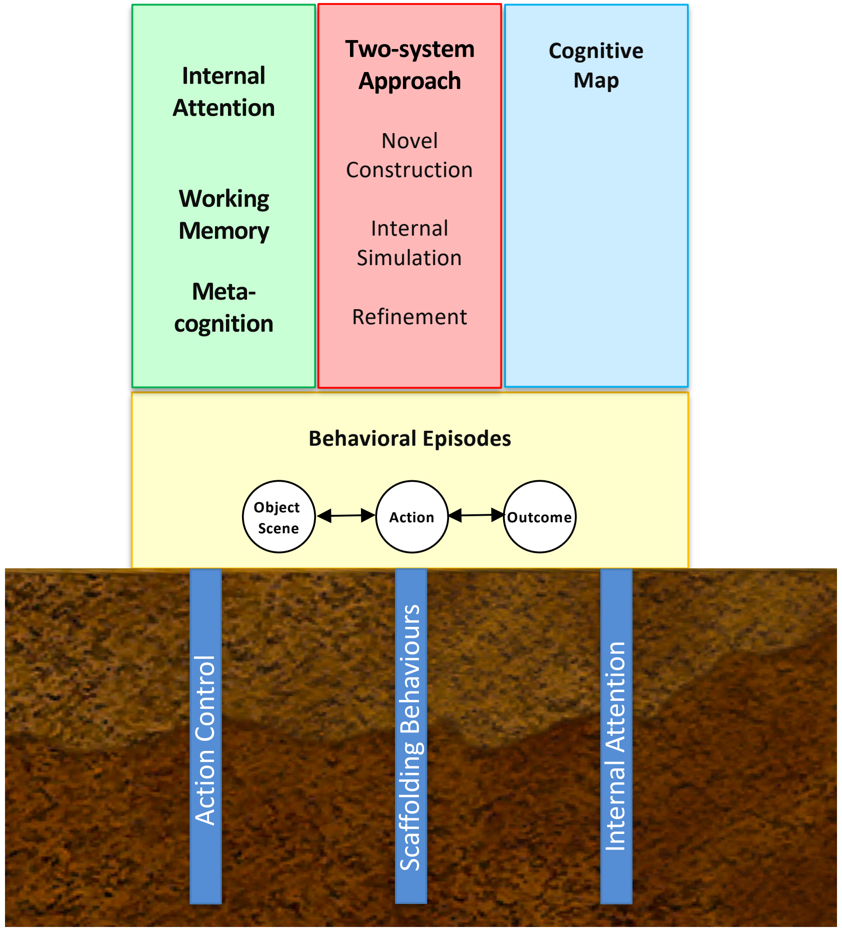
Situation Model Framework



More disparate sources in memory:

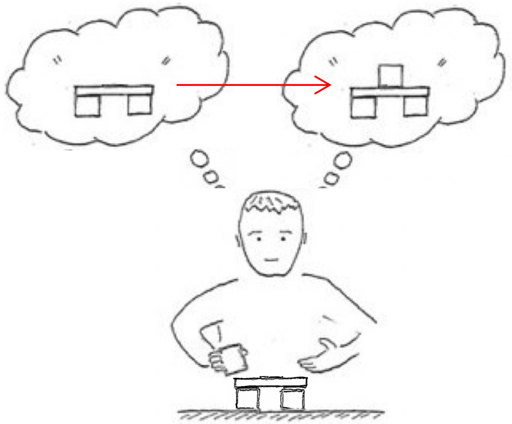
- Episodic memory decoupled from autobiographical experience
- Procedural memory of disparate skills
- Semantic memory that binds elements in a cohesive narrative

Situation Model Framework



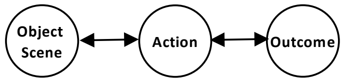
Situation Model Framework

Mechanisms for
constructing, simulating, enacting, refining, and assimilating
behavioural episodes



Behavioural episode

- Joint **perception-action** representation
- Captures causal relationships between objects, scenes, actions, action outcomes

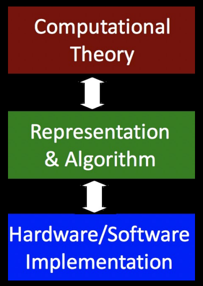


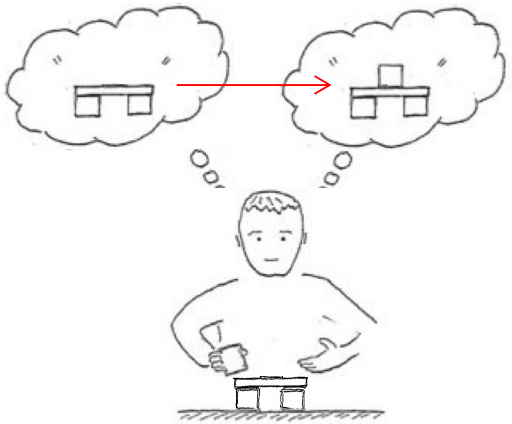
Situation Model Framework

Process

Mechanisms for
constructing, simulating, enacting, refining, and assimilating
behavioural episodes

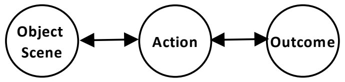
Representation





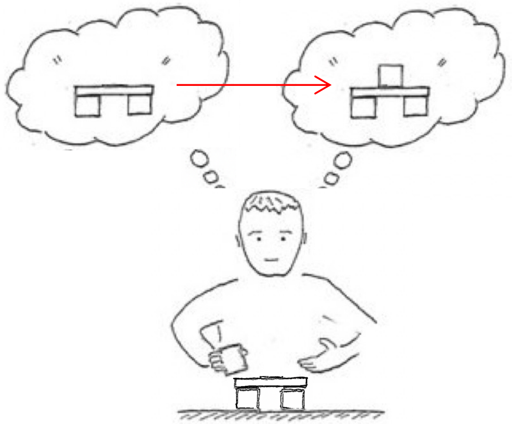
Behavioural episode

- Joint **perception-action** representation
- Captures causal relationships between objects, scenes, actions, action outcomes



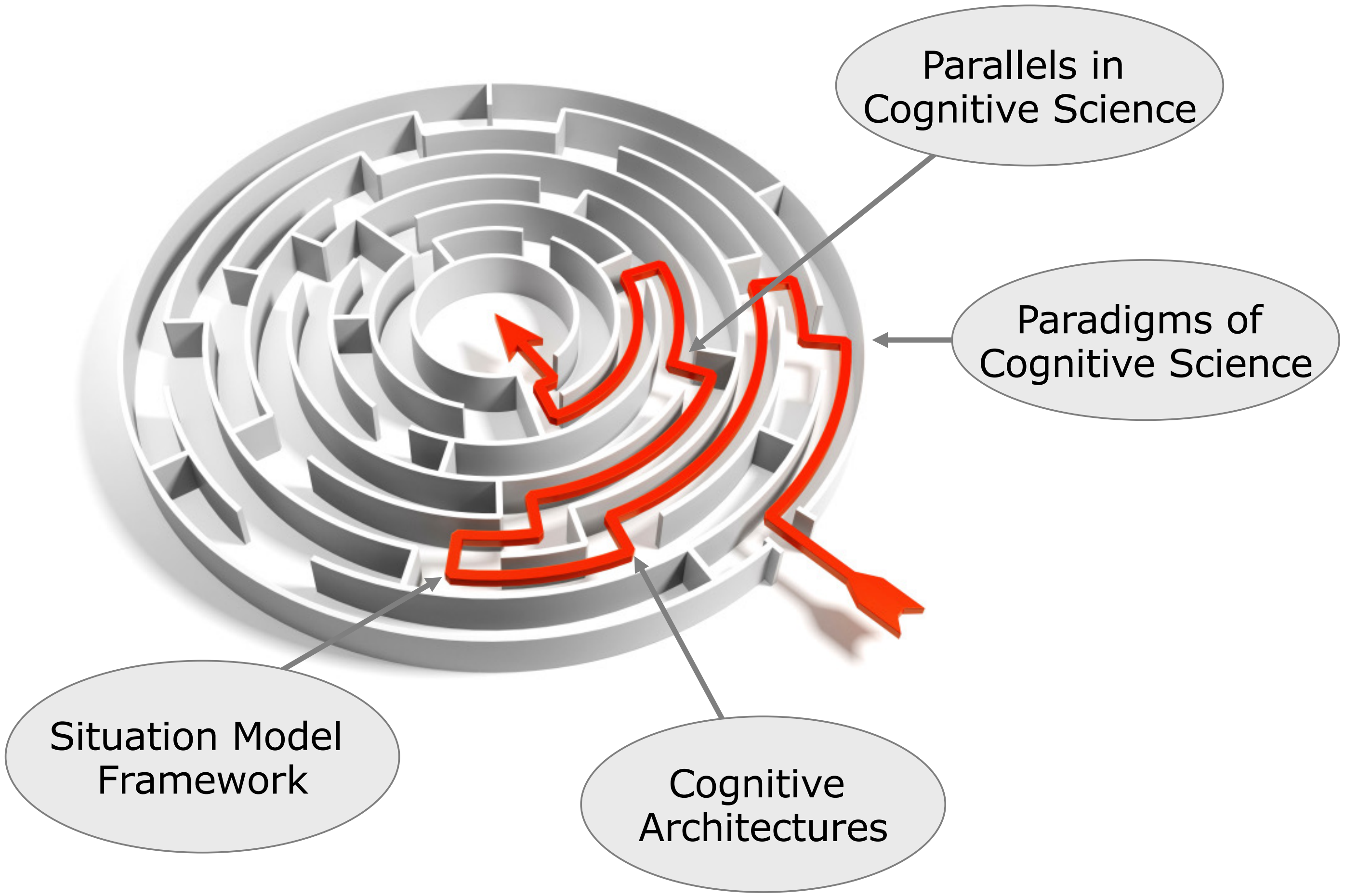
Situation Model Framework

Probehandeln



Trial treatment: mental execution of an action or consideration of alternative actions to reach a decision

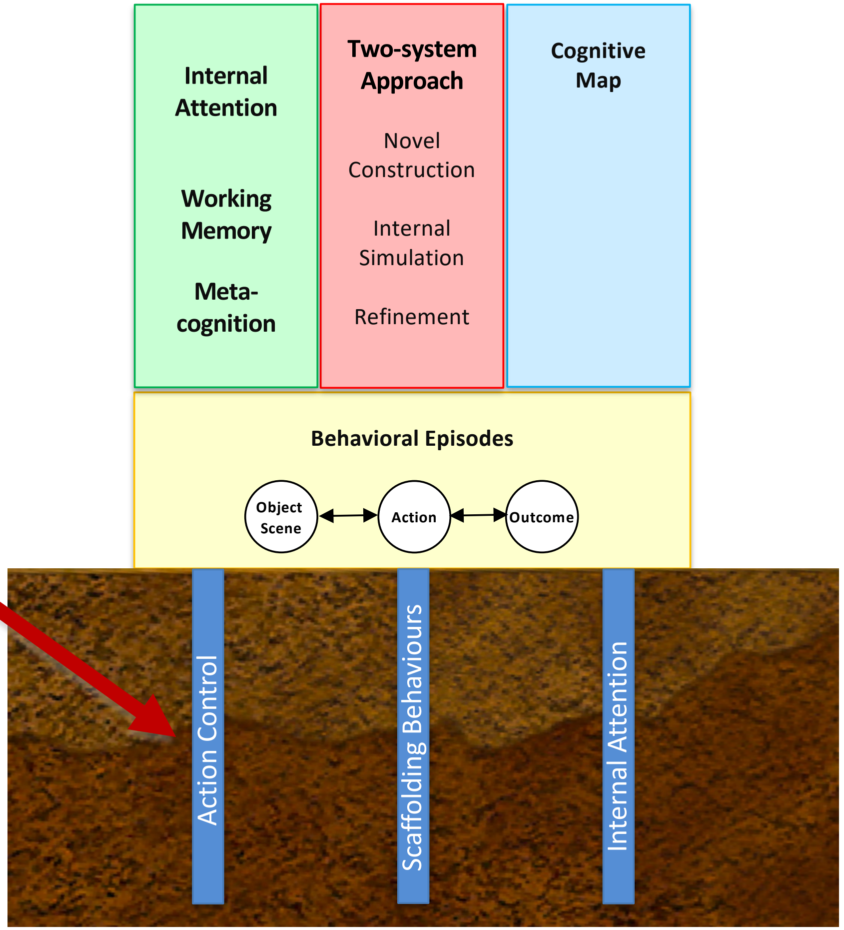
https://www.spektrum.de/lexikon/psychologie/probehandeln-internes/11849


Parallels in Cognitive Science
Paradigms of Cognitive Science
Situation Model Framework
Cognitive Architectures

Situation Model Framework

"Cognition is effective action"

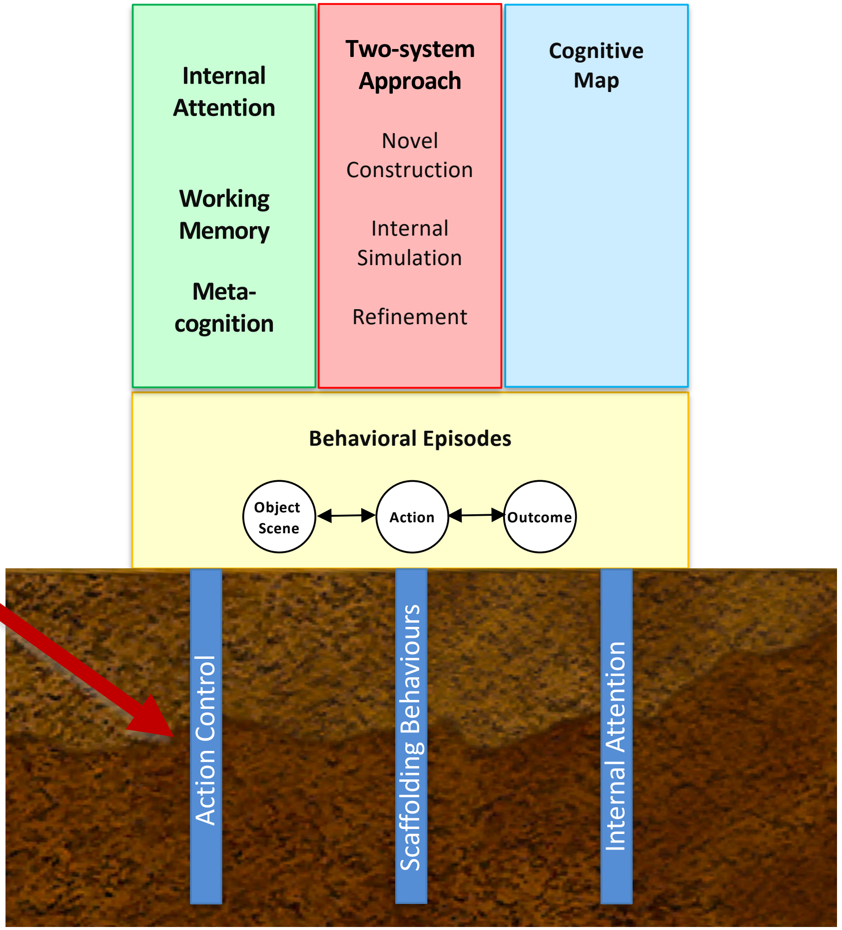
H. Maturana and F. Varela.
The Tree of Knowledge —
The Biological Roots of Human Understanding.
NewScience Library, Boston & London, 1987



Situation Model Framework

"Actions are directed to the future and must predict what is going to happen next."

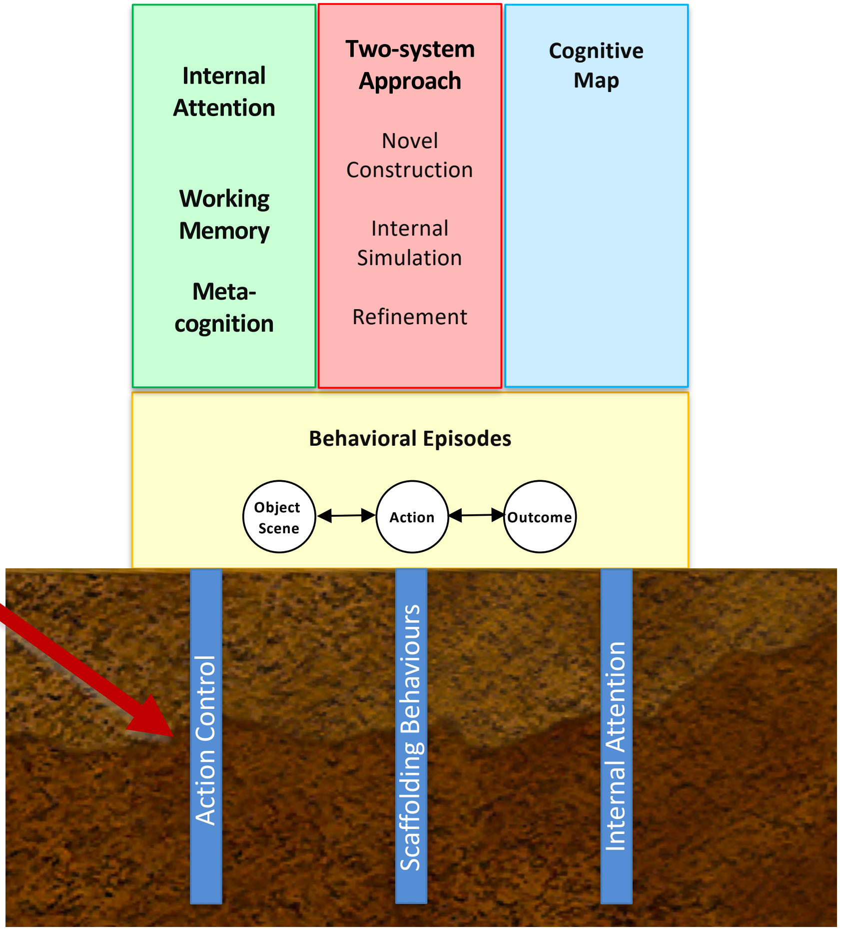
C. von Hofsten. An action perspective on motor development. Trends in Cognitive Sciences, 8:266–272, 2004.



Situation Model Framework

"Most neonatal behaviours are prospective and flexible goal-directed actions"

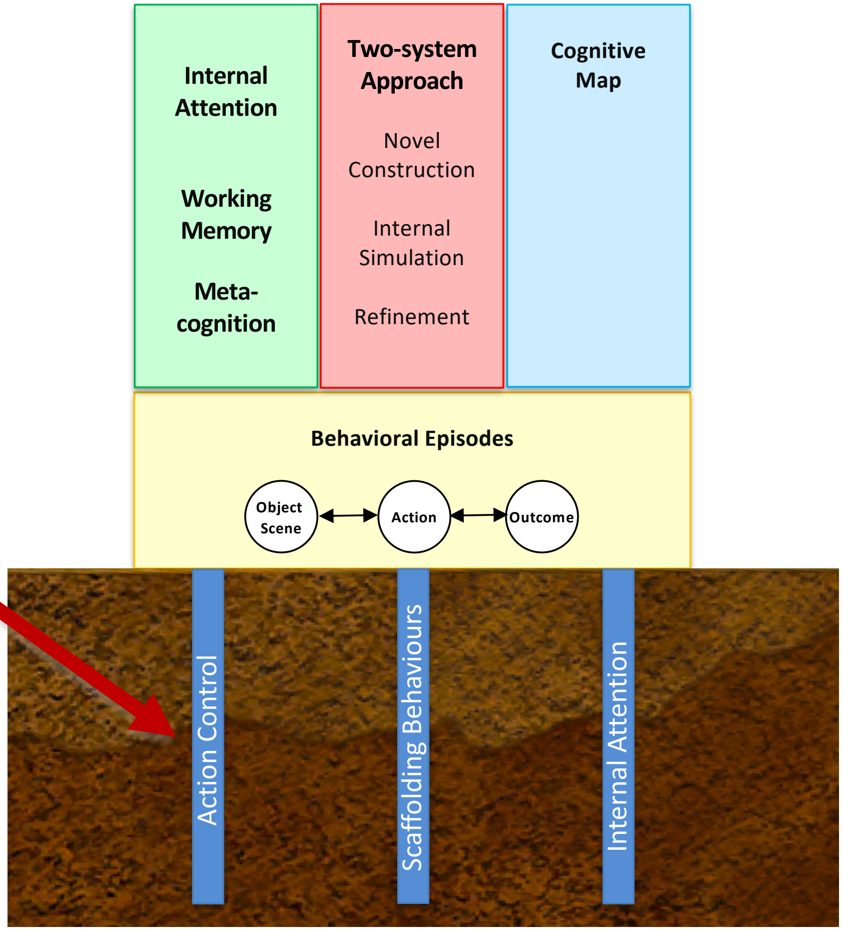
C. von Hofsten. Action, the foundation for cognitive development. Scandinavian Journal of Psychology, 50:617–623, 2009.



Situation Model Framework

"Cognitive development has to do with expanding the prospective control of actions."

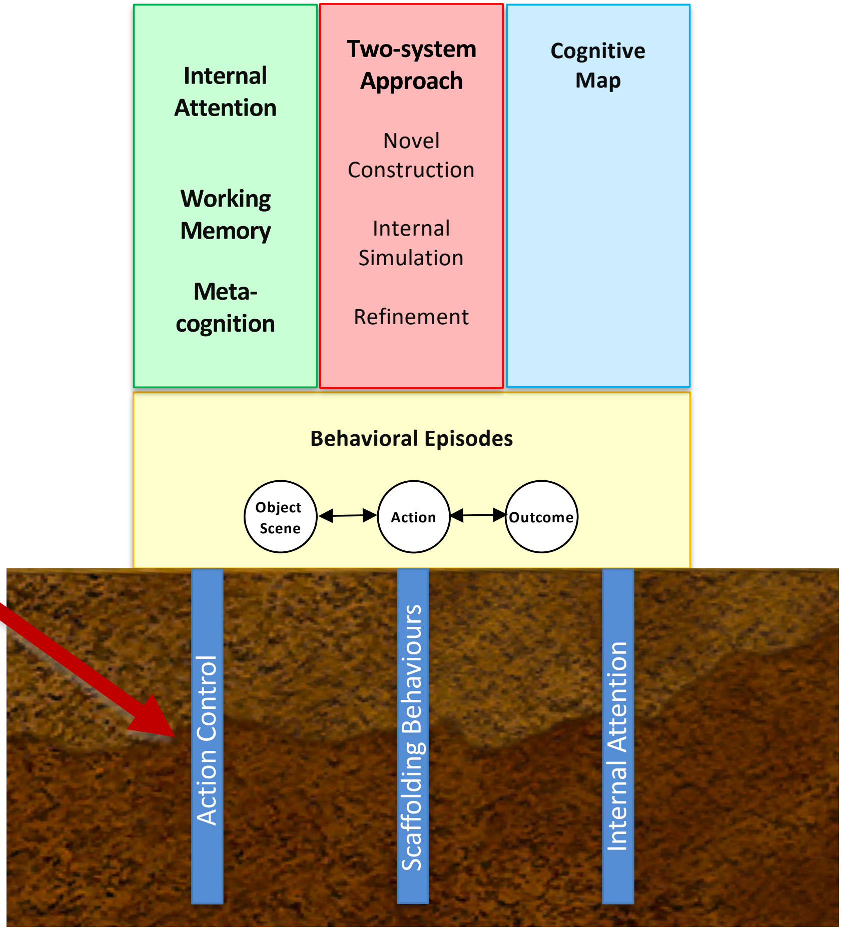
C. von Hofsten. Action in development. Developmental Science, 10(1):54–60, 2007.



Situation Model Framework

"Expanding one's repertoire of actions is a powerful motivation, overriding efficacy in achieving a goal"

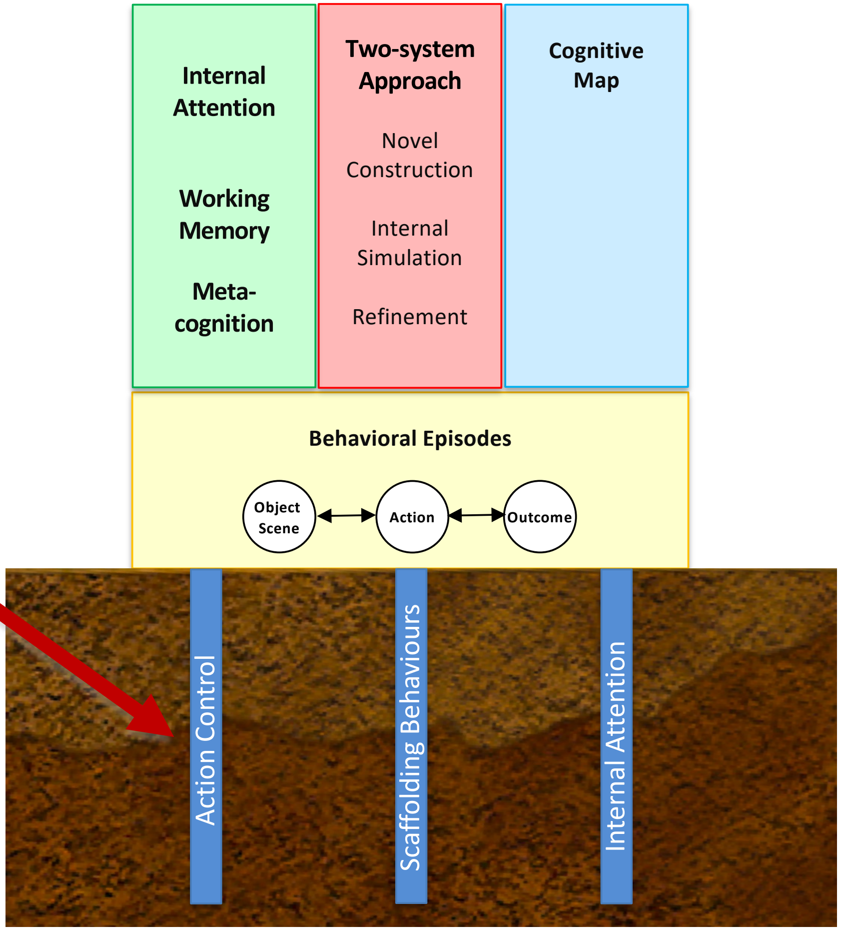
D. Vernon, C. von Hofsten, and L. Fadiga. A Roadmap for Cognitive Development in Humanoid Robots, Springer, Berlin, 2010.



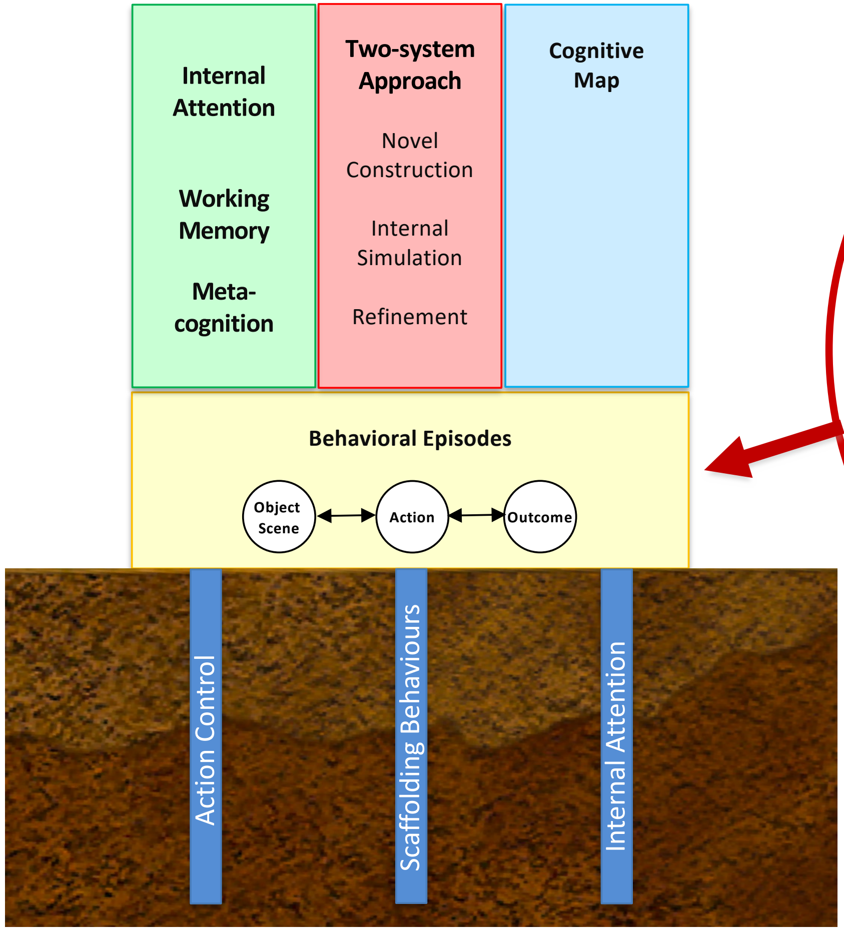
Situation Model Framework

"a cognitive agent continually anticipates the need to act and it anticipates the outcome of those actions"

D. Vernon, C. von Hofsten, and L. Fadiga. A Roadmap for Cognitive Development in Humanoid Robots, Springer, Berlin, 2010.



Situation Model Framework

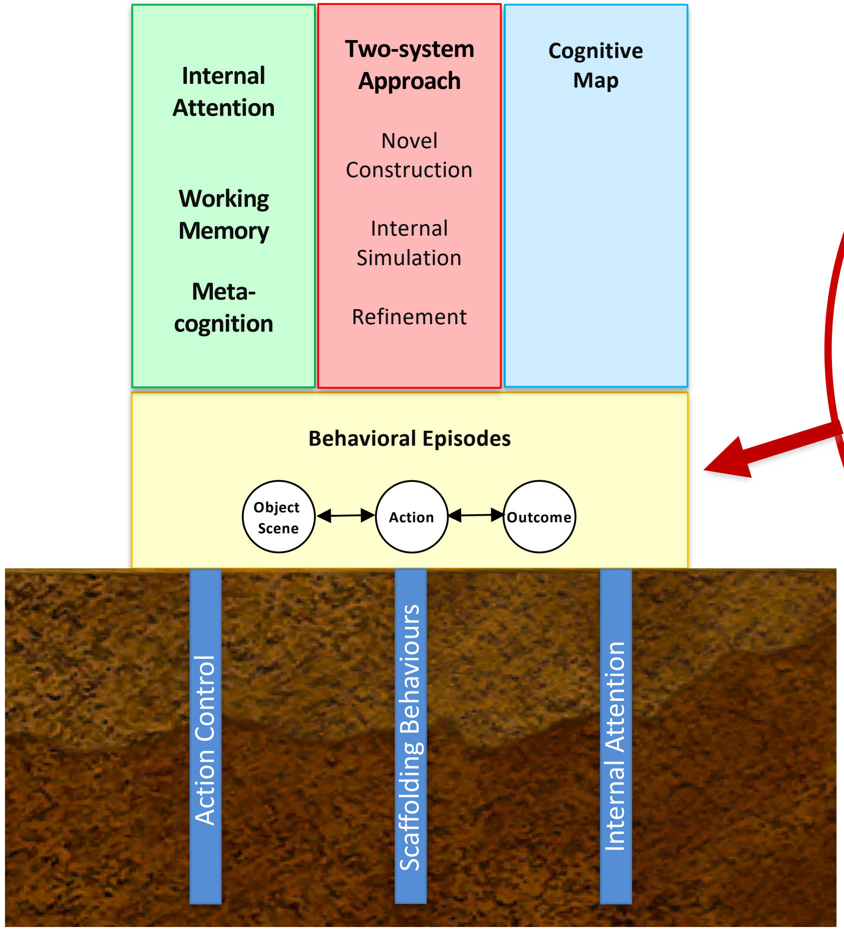


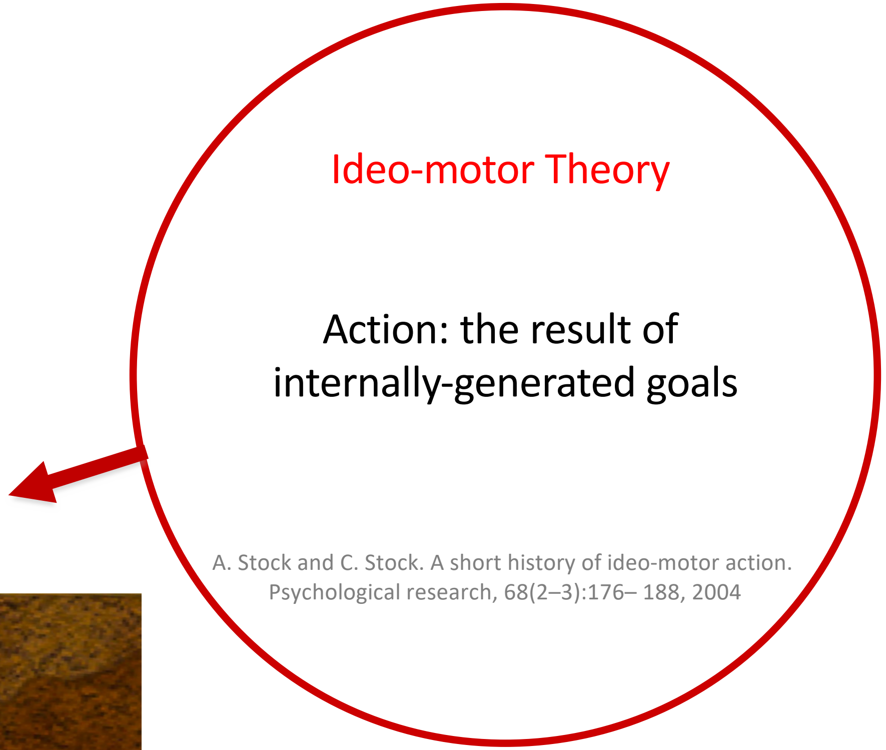
Sensory-motor Theory

Actions: reactive responses to sensory stimuli

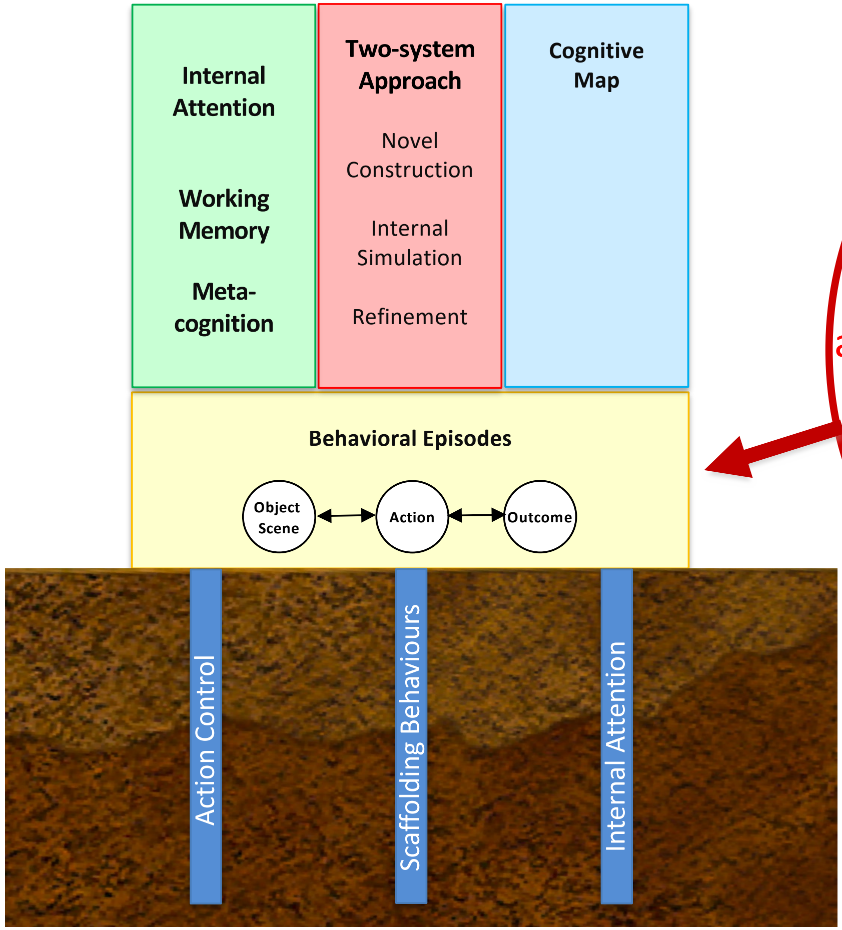
Perception and action use distinct and separate representational frameworks

Situation Model Framework





Situation Model Framework

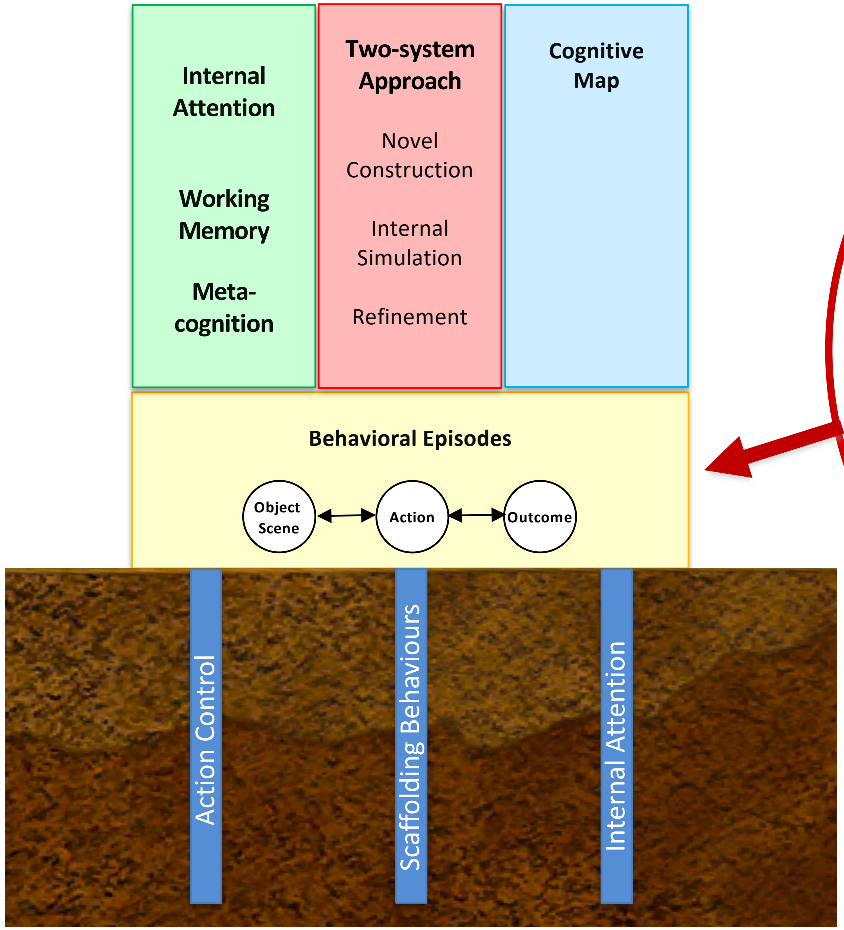


Ideo-motor Theory

The selection and control of a goal-directed movement depends on anticipation of the sensory consequence of accomplishing the intended action

A. Stock and C. Stock. A short history of ideo-motor action. Psychological research, 68(2–3):176– 188, 2004

Situation Model Framework



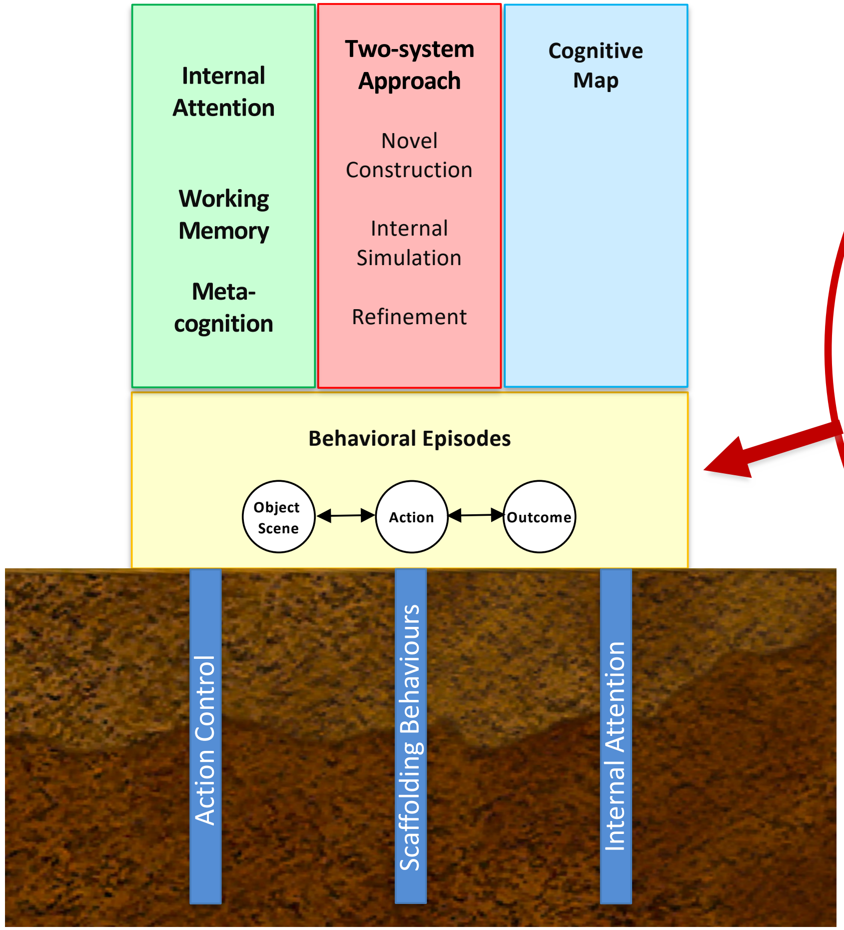
Ideo-motor Theory

Select prospectively-guided intention-directed goal-focussed action

with the specific movements being adaptively controlled as the action is executed

A. Stock and C. Stock. A short history of ideo-motor action. Psychological research, 68(2–3):176– 188, 2004

Situation Model Framework

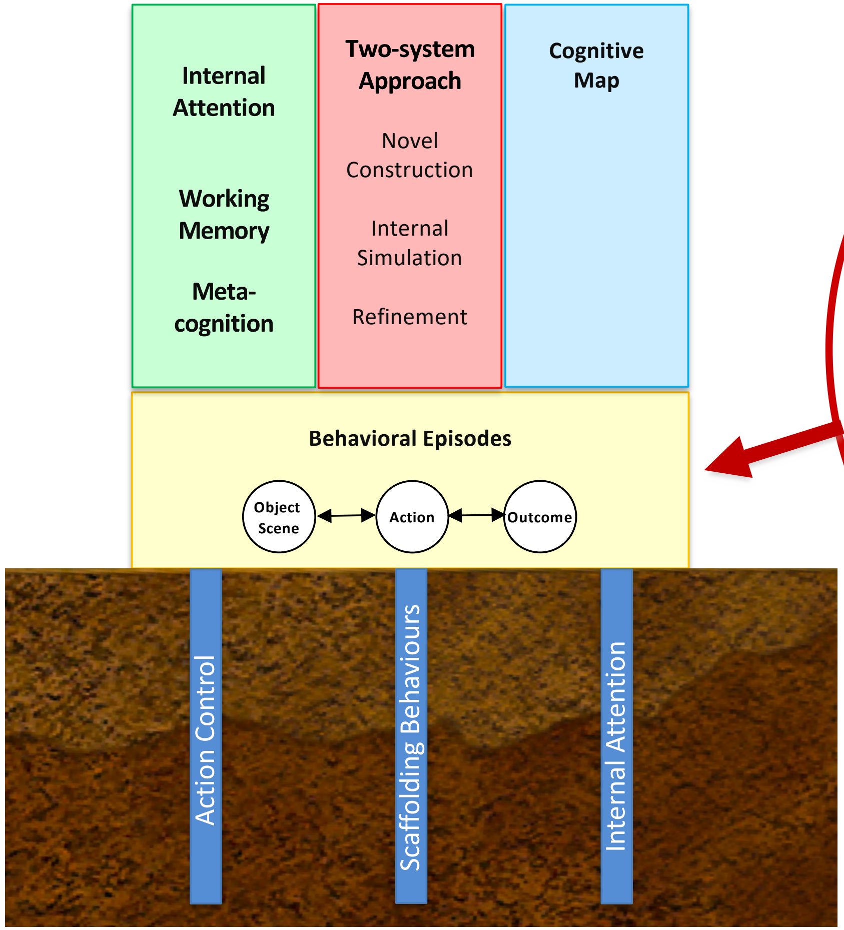


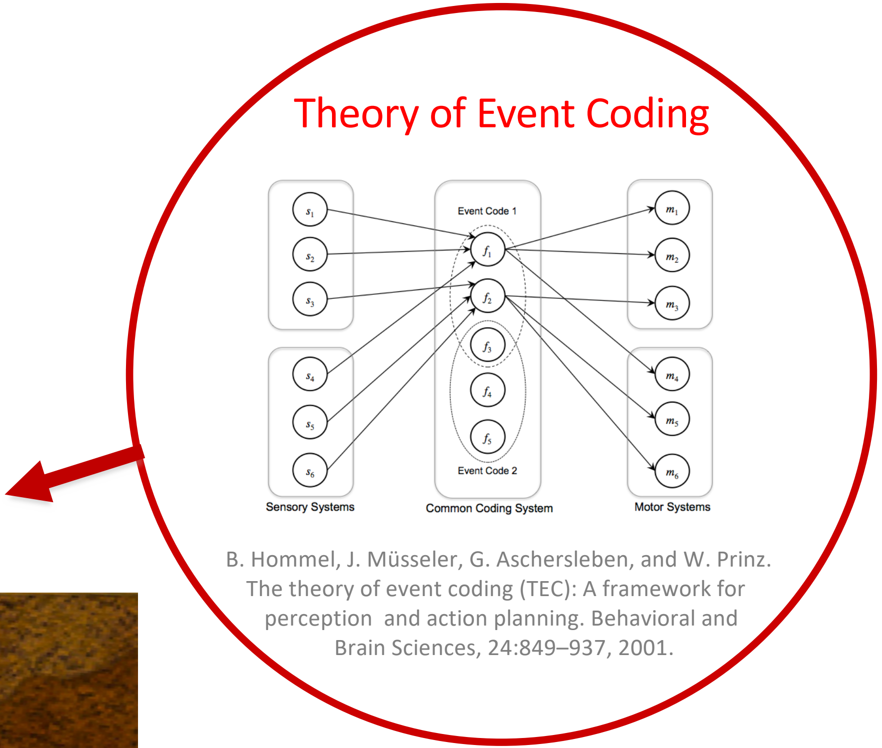
Ideo-motor Theory

Perception and action share a common representational framework

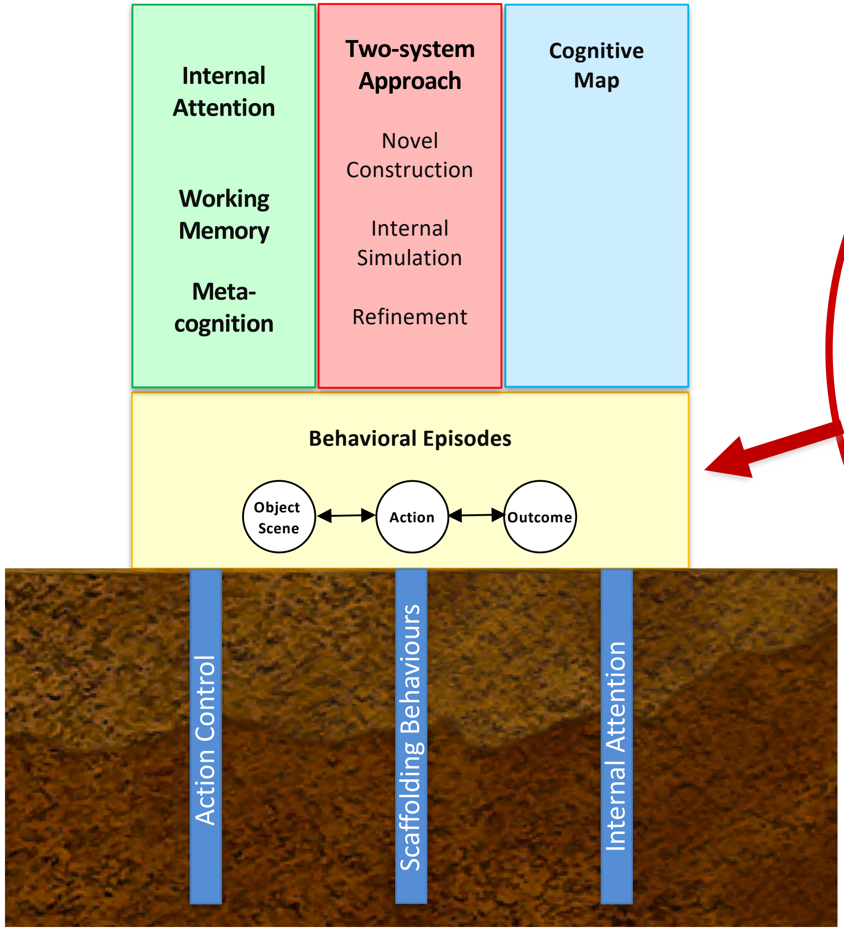
A. Stock and C. Stock. A short history of ideo-motor action. Psychological research, 68(2–3):176– 188, 2004

Situation Model Framework





Situation Model Framework

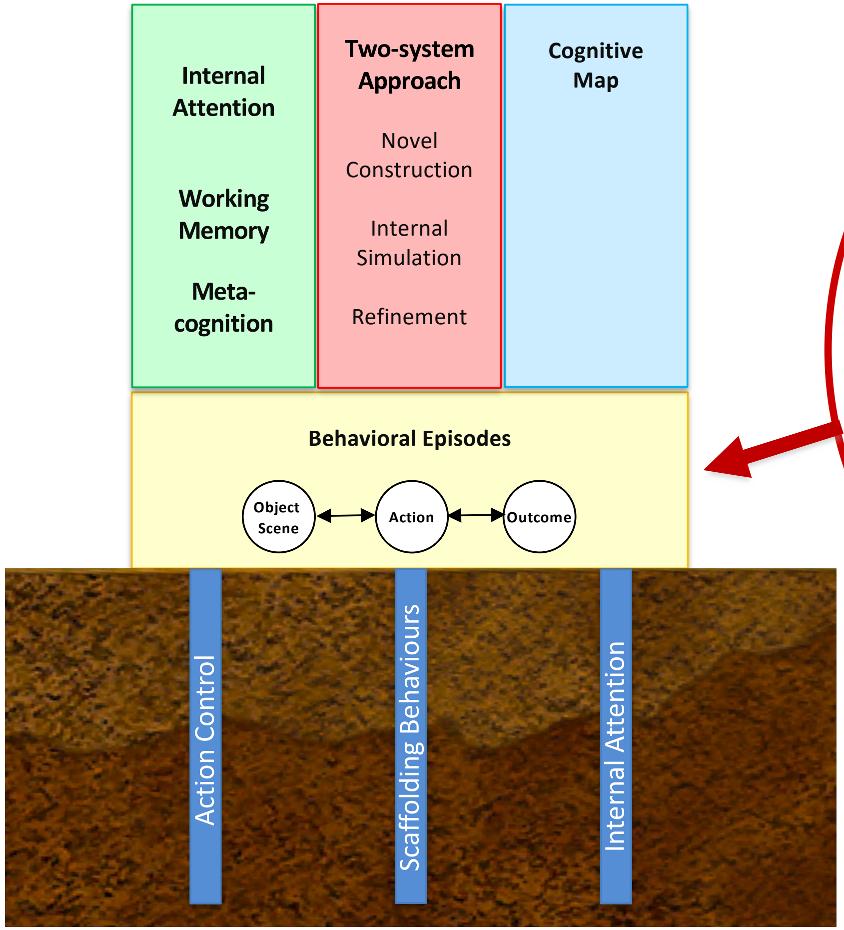


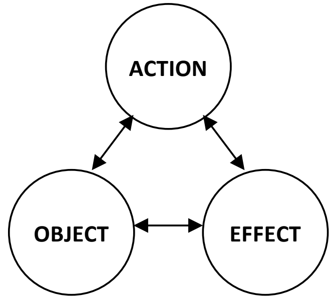
Ideo-motor Theory

Goal Trigger Hypothesis

B. Hommel, J. Müsseler, G. Aschersleben, and W. Prinz. The theory of event coding (TEC): A framework for perception and action planning. Behavioral and Brain Sciences, 24:849–937, 2001.

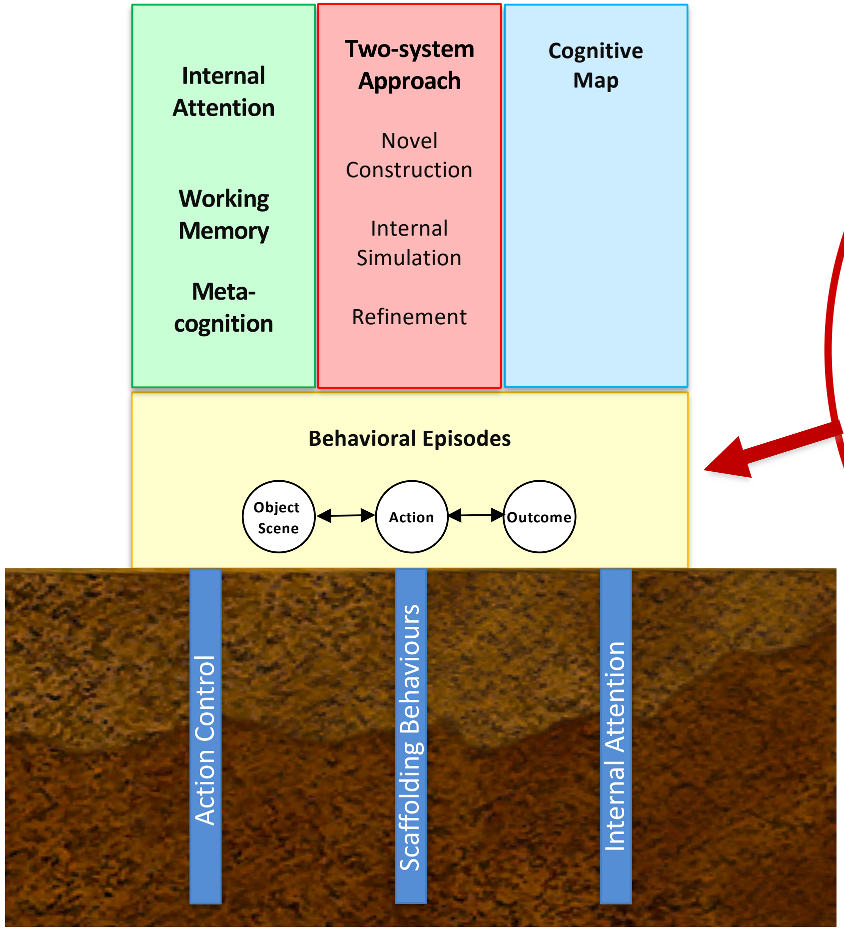
Situation Model Framework





N. Krüger, C. Geib, J. Piater, R. Petrickb, M. Steedman, F. Wörgötter, A. Ude, T. Asfour, D. Kraft, D. Omrcen, A. Agostini, and R. Dillmann. Object–action complexes: Grounded abstractions of sensory–motor processes. Robotics and Autonomous Systems, 59:740–757, 2011.

Situation Model Framework

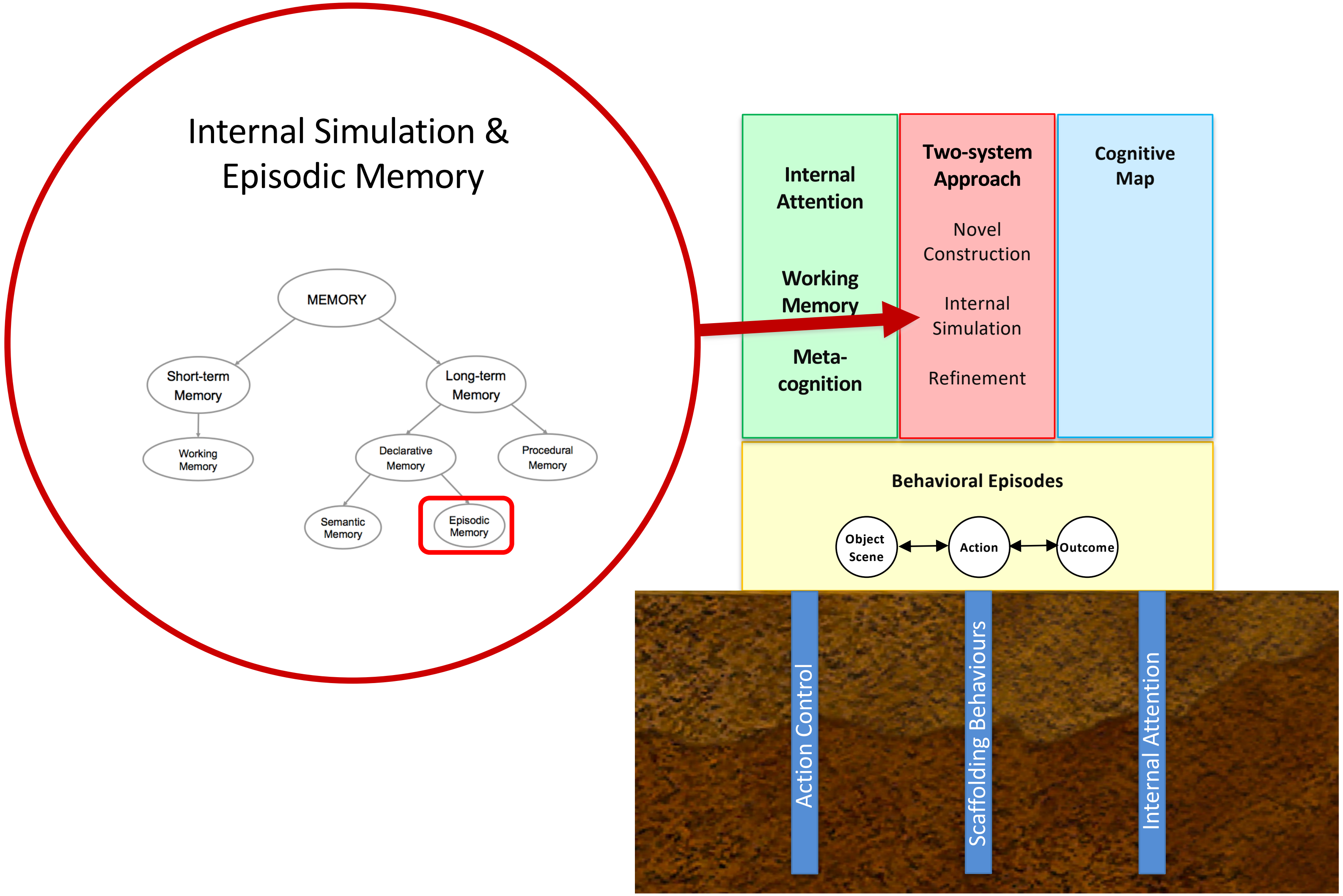


Abstract Representations

"Once a goal has been established, the abstract kinematic structure of a movement and the final state of the end effector (e.g., a hand) may be planned"

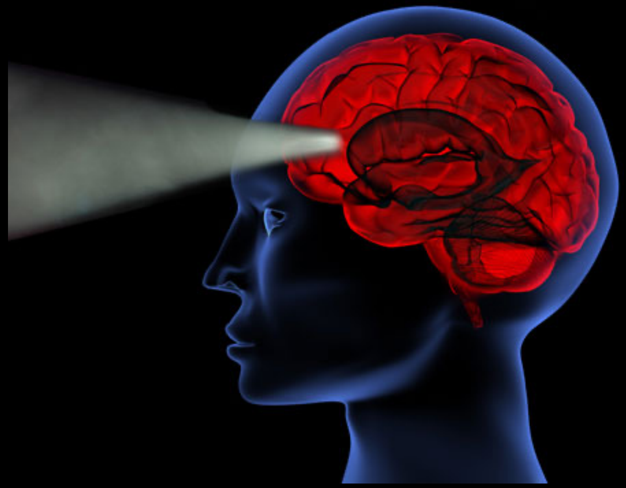
D. McNamee and D. M. Wolpert. Internal models in biological control. Annual Review of Control, Robotics, and Autonomous Systems, 2:339–364, 2019.

Situation Model Framework



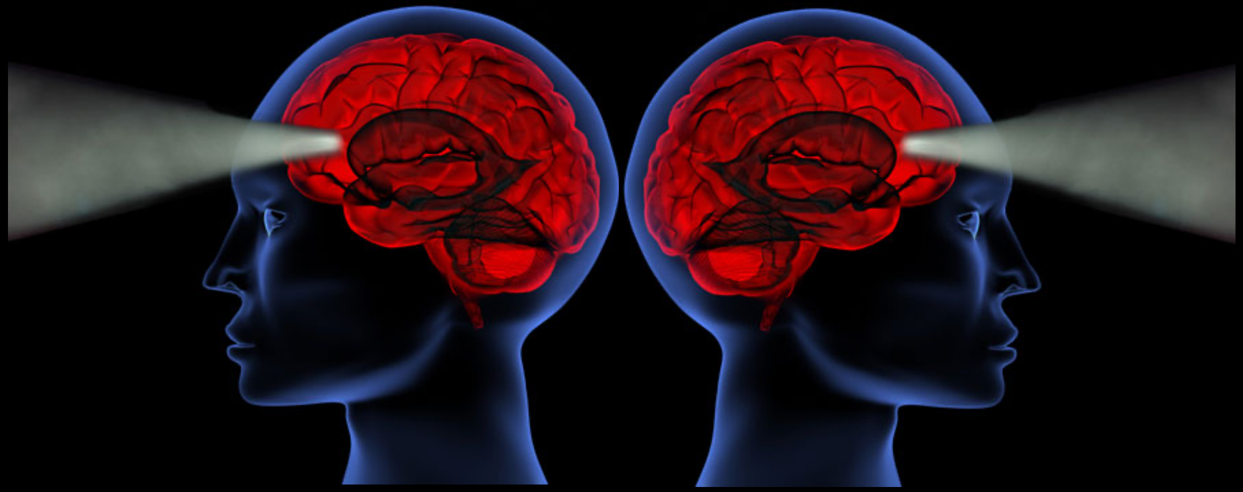
Episodic Memory

The Past



Past events are
reconstructed ...

Episodic Memory



Past events are
reconstructed ...

To allow the agent
to **pre-experience** the future

Episodic Future Thinking

The Past

The Future

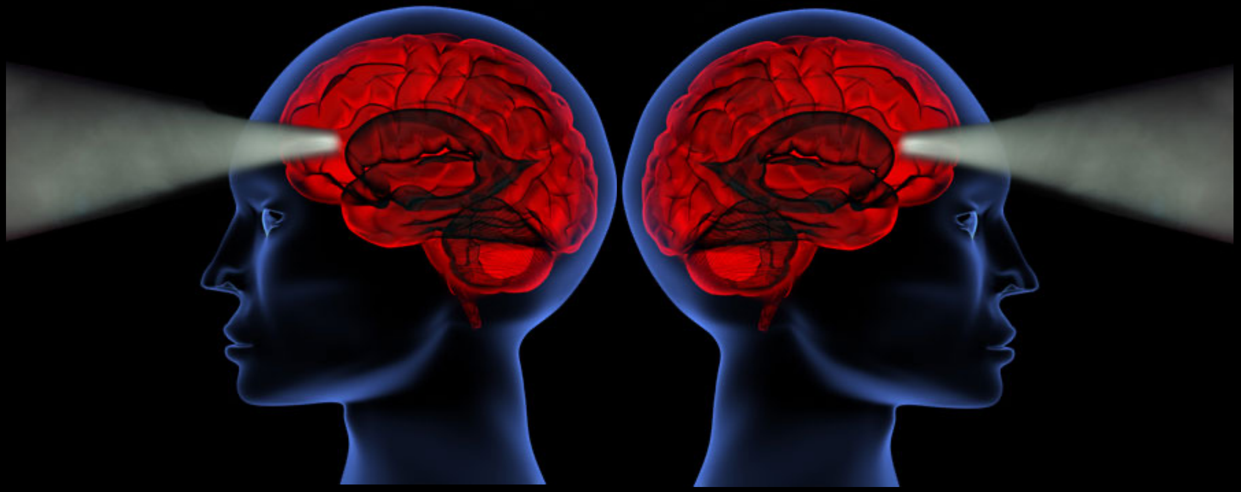
Past events are **reconstructed ...**

To allow the agent to **pre-experience** the future

C. M. Atance and D. K. O'Neill, "Episodic future thinking," Trends in Cognitive Sciences, vol. 5, no. 12, pp. 533–539, 2001.

Constructive Episodic Simulation Hypothesis

The Past



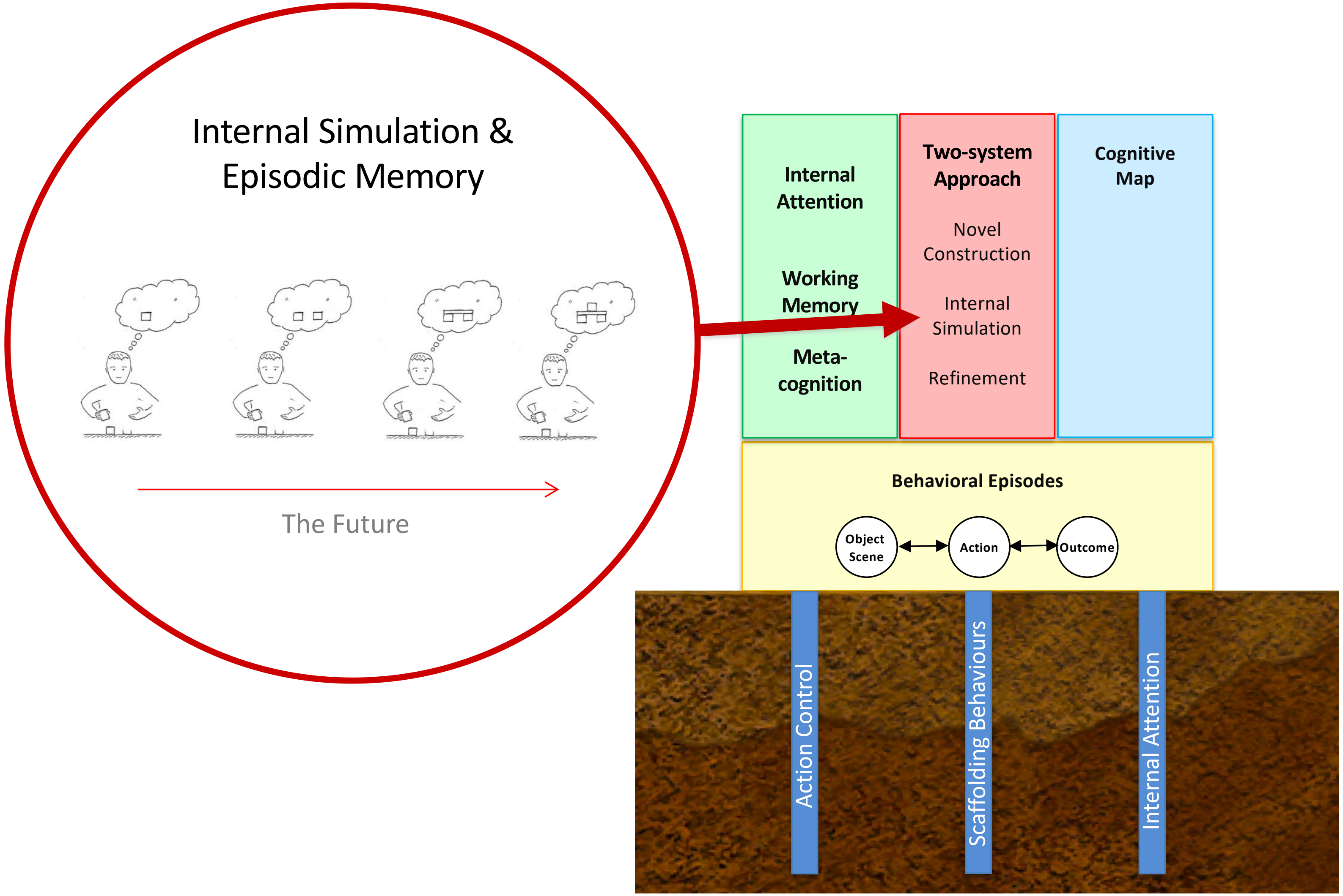
The Future

Past events are **reconstructed ...**

To allow the agent to **pre-experience** the future

D. L. Schacter and D. R. Addis, "The cognitive neuroscience of constructive memory: Remembering the past and imagining the future," Philosophical Transactions of the Royal Society B, vol. 362, pp. 773–786, 2007.

Situation Model Framework

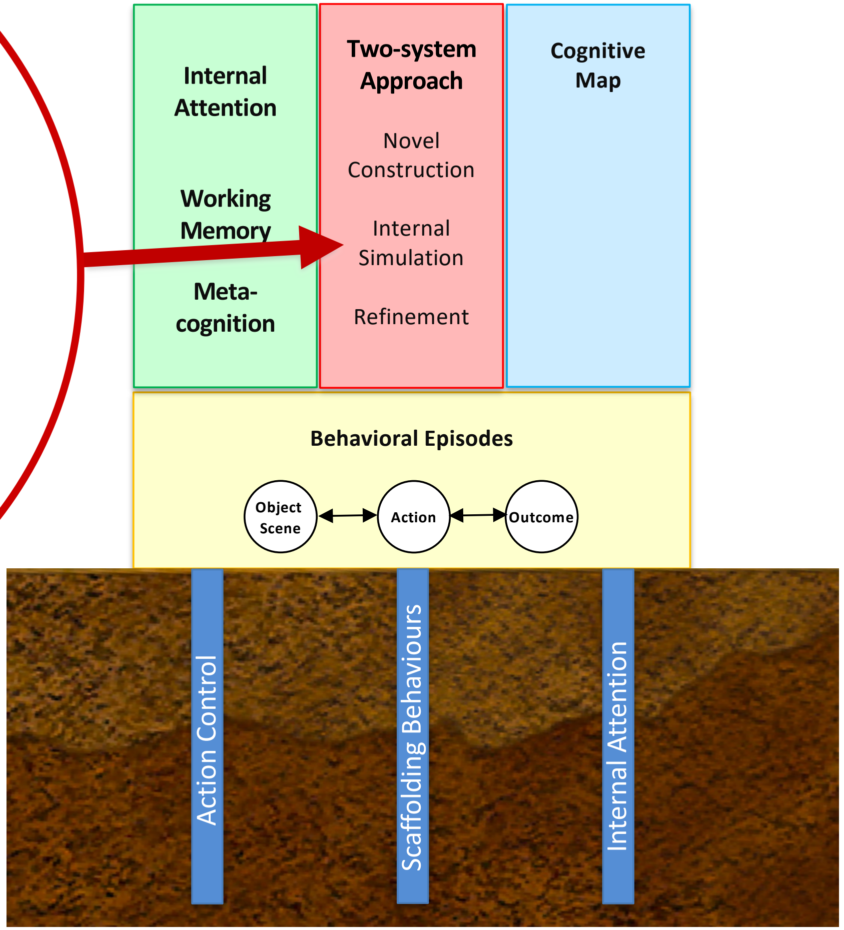


Situation Model Framework

"It's a poor sort of memory that only works backwards"

Remarks of the White Queen to Alice in Lewis Carroll's Through the Looking Glass

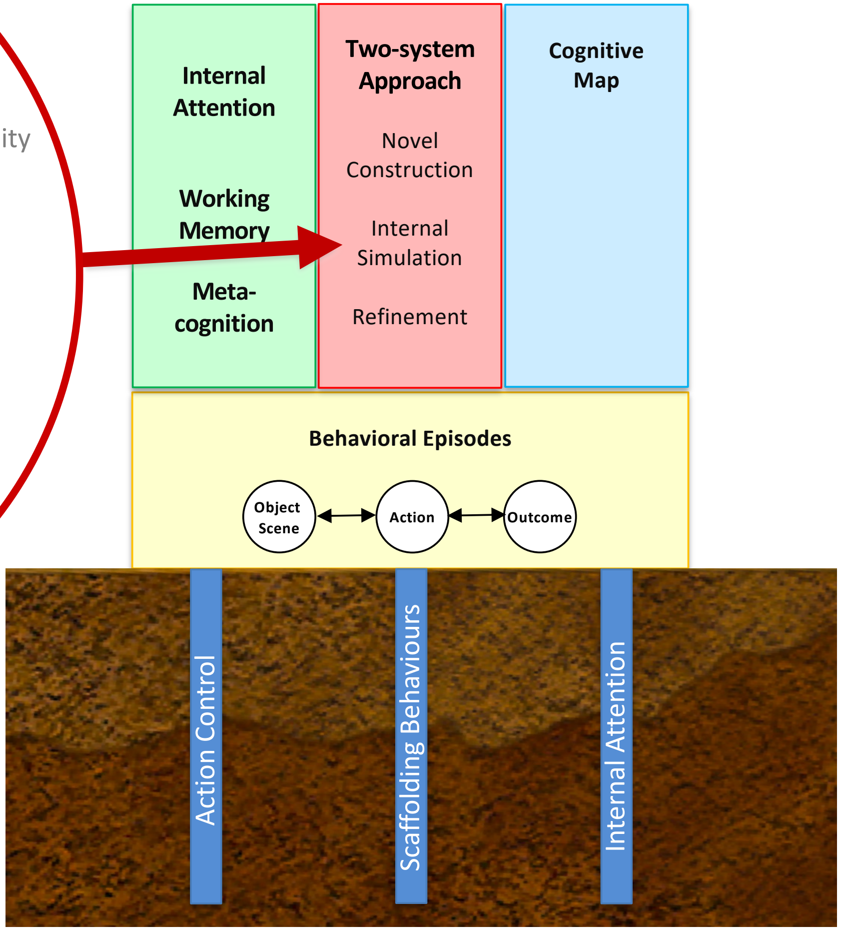
Memory is Prospective



Situation Model Framework

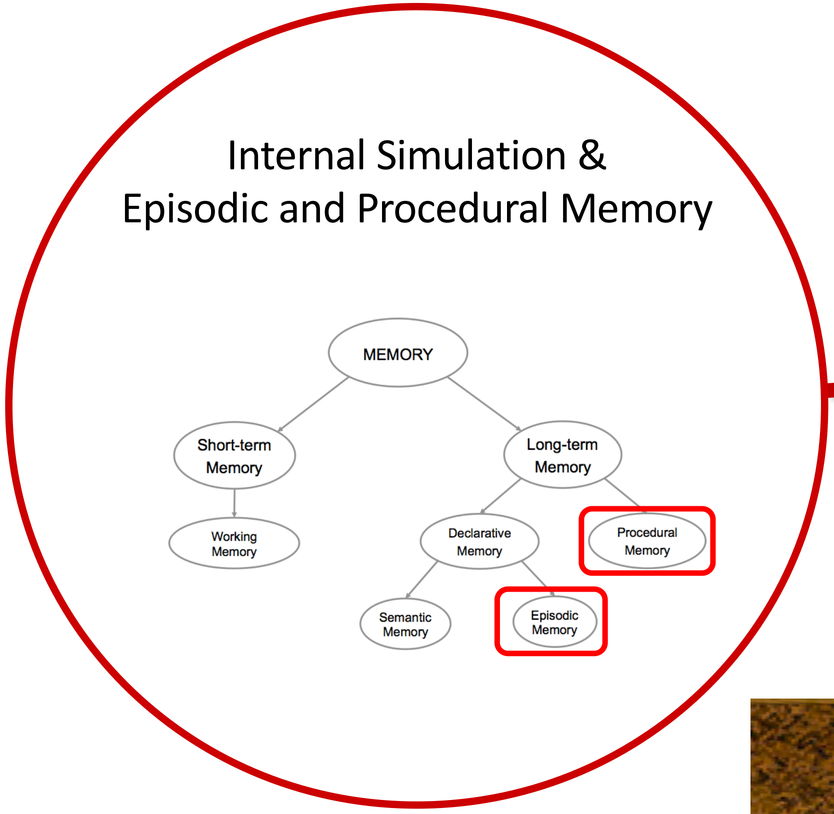
"It's a poor sort of memory that only remembers what has actually happened"

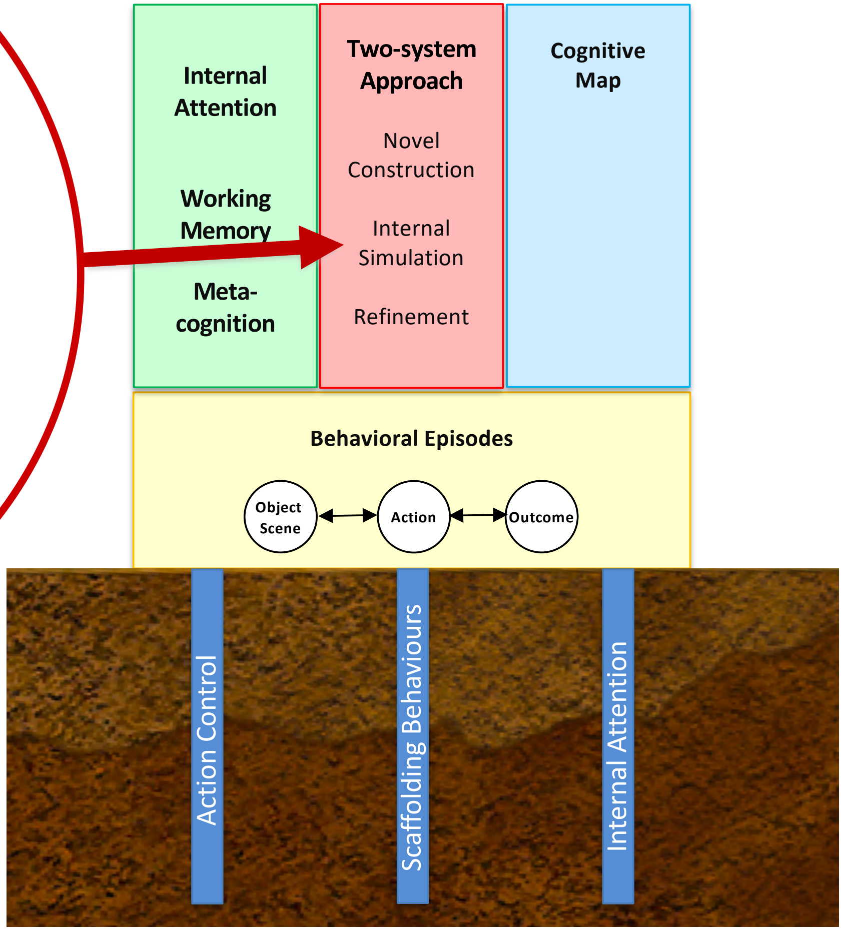
Remarks by Tom Ziemke during a talk at Linköping University



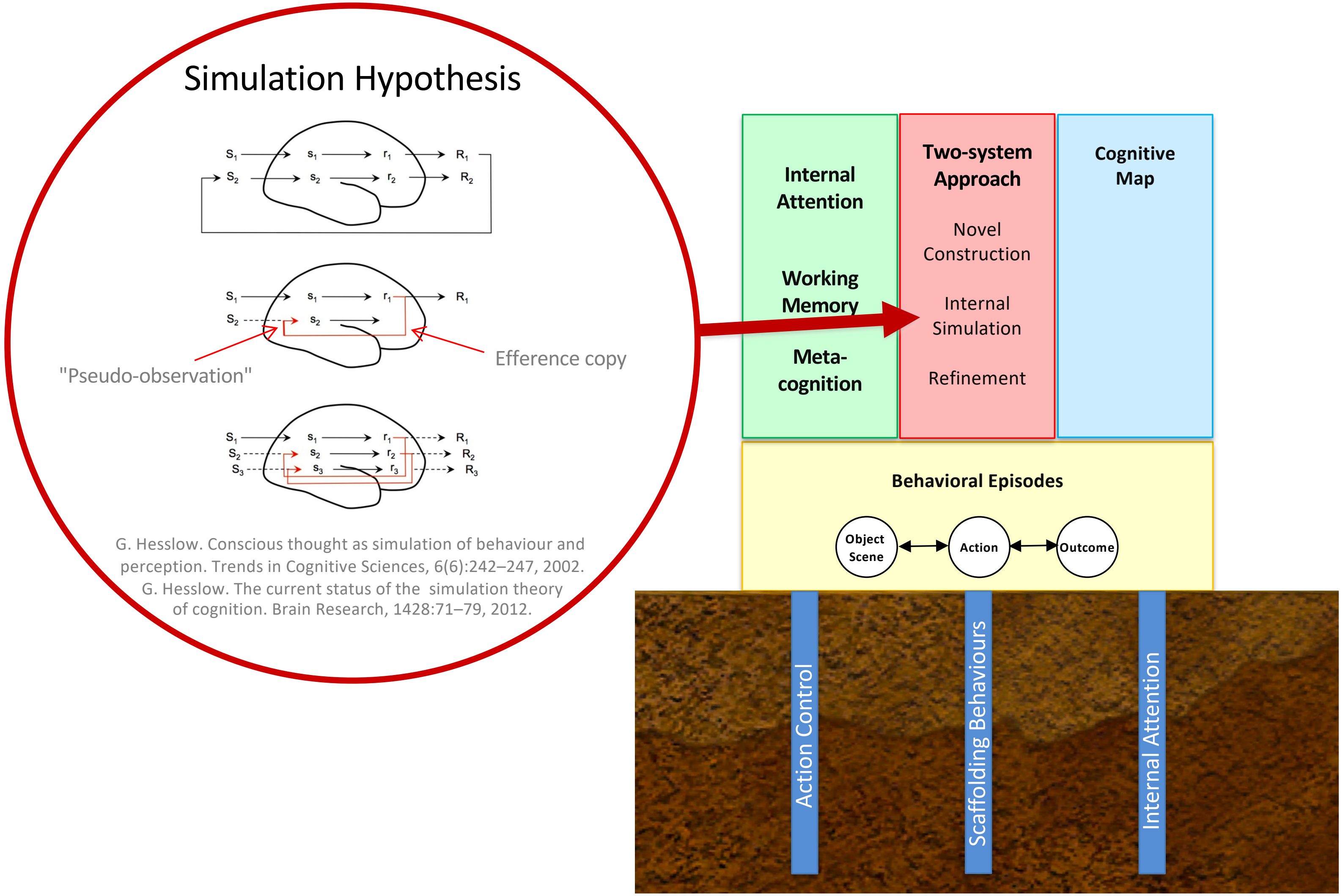
Memory is Constructive

Situation Model Framework

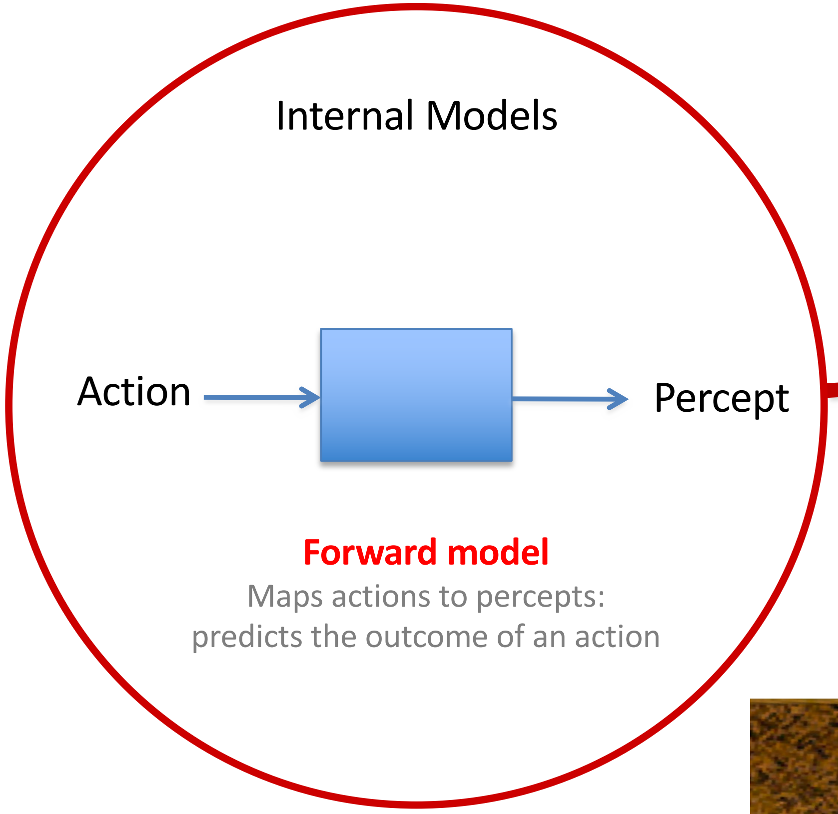


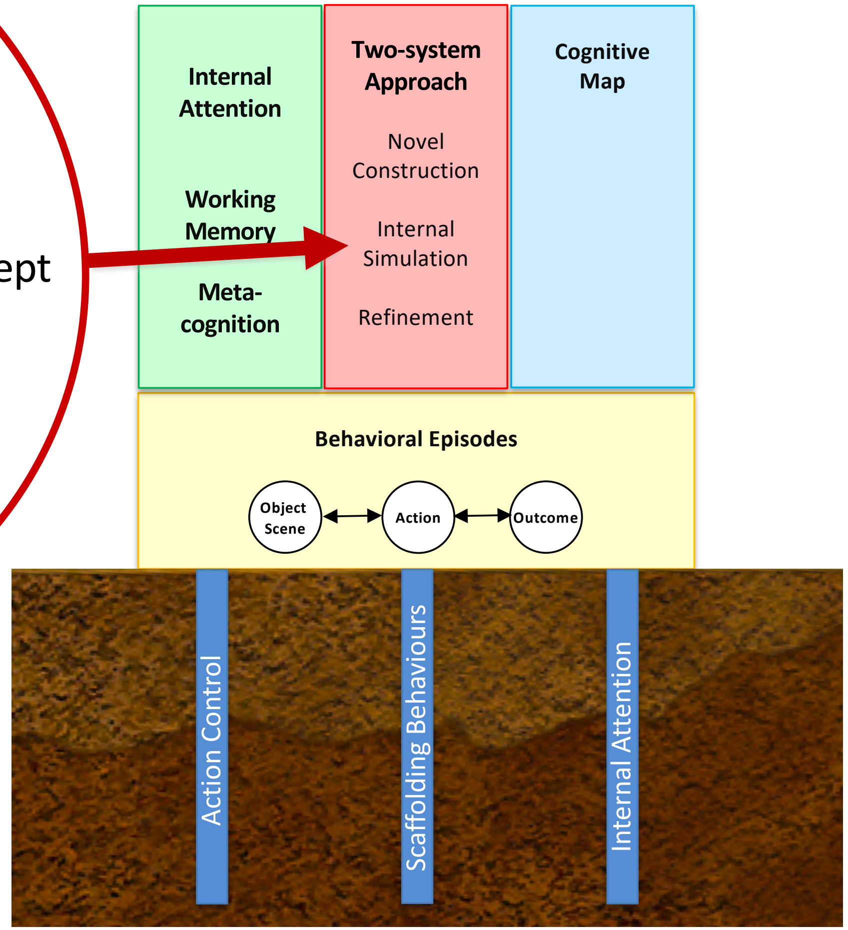


Situation Model Framework

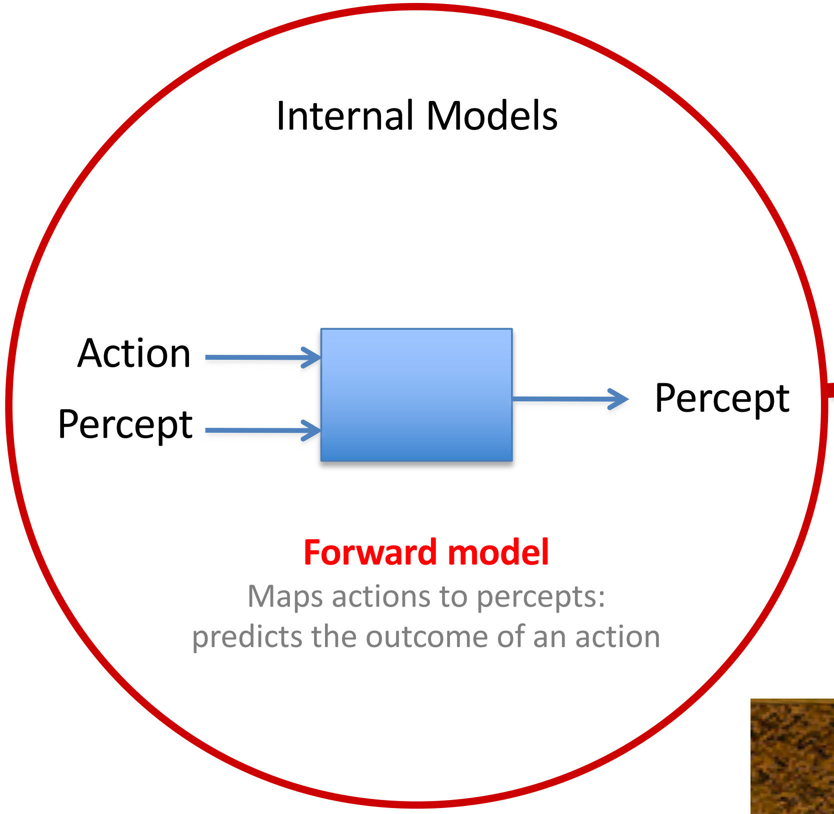


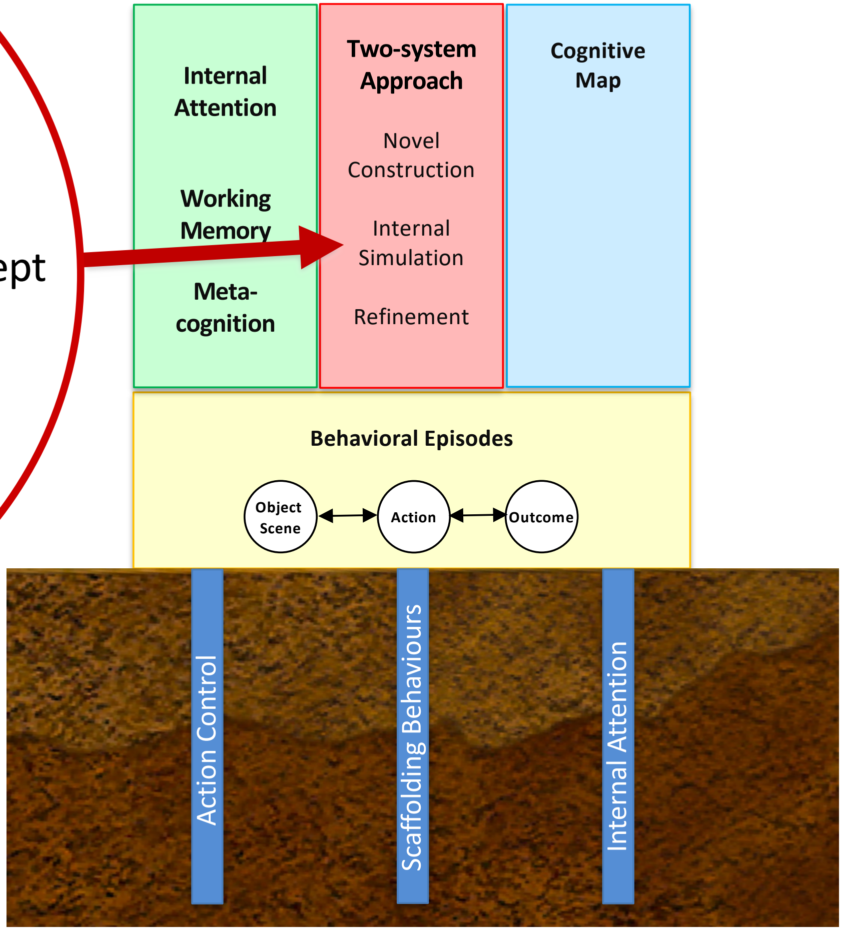
Situation Model Framework



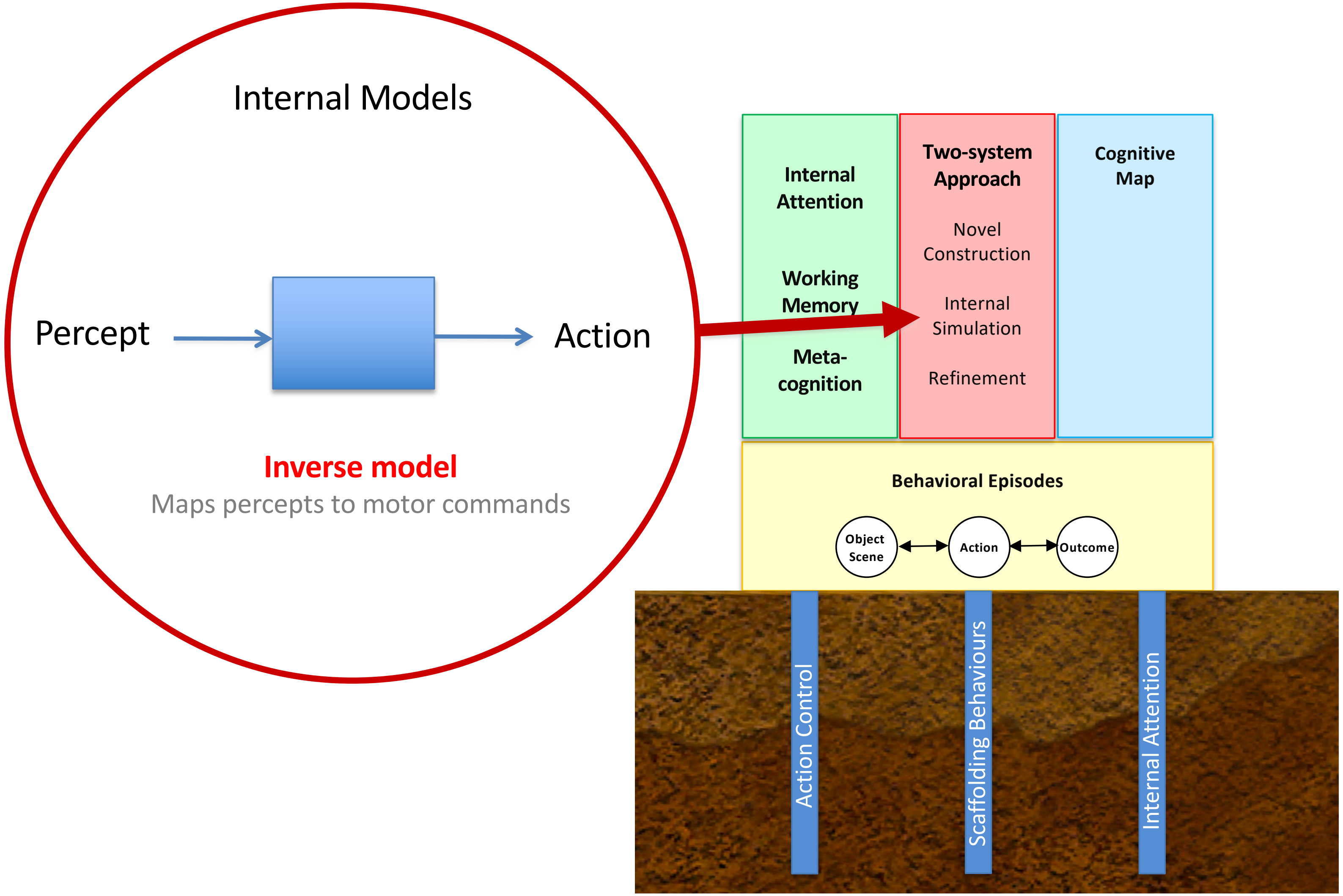


Situation Model Framework

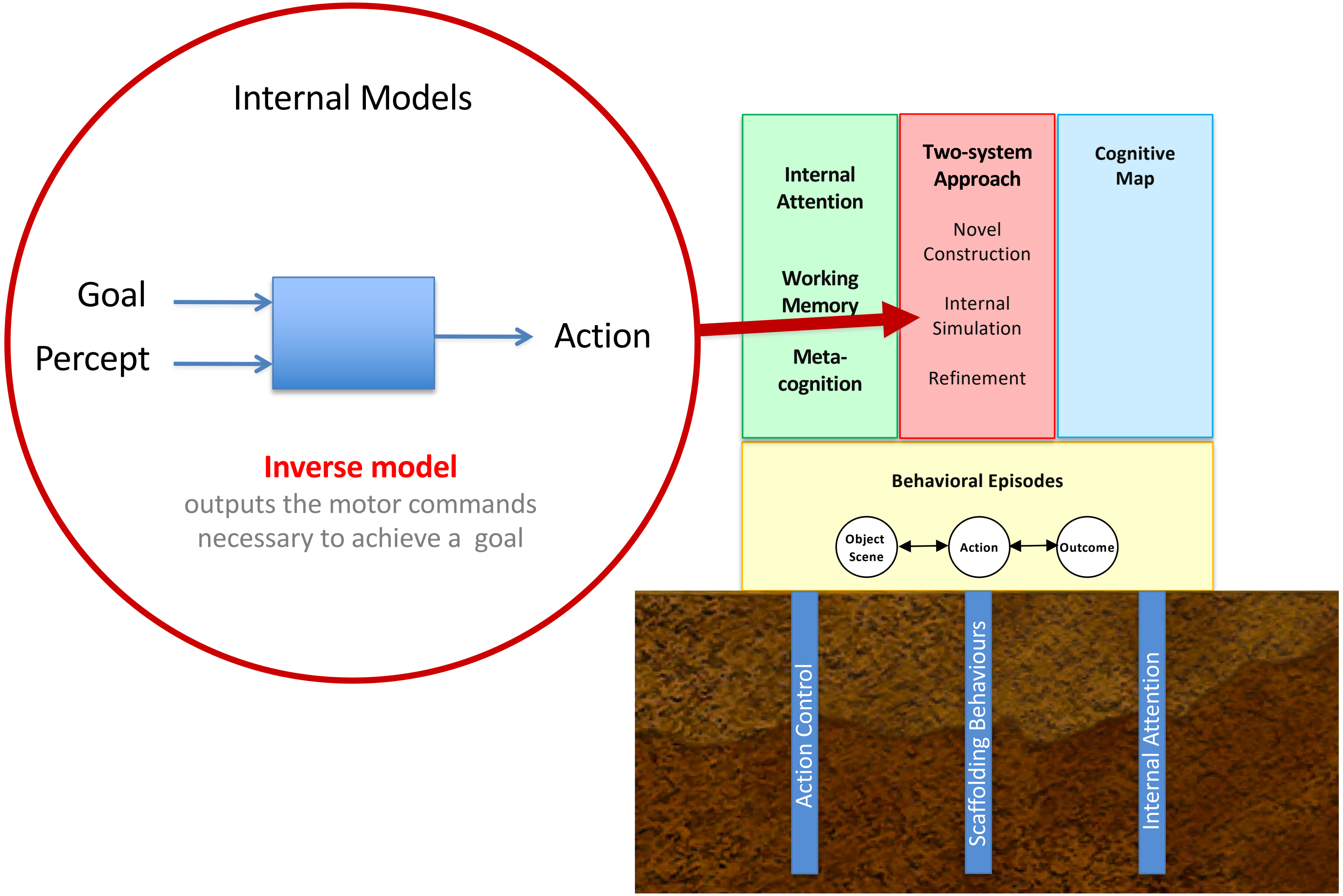




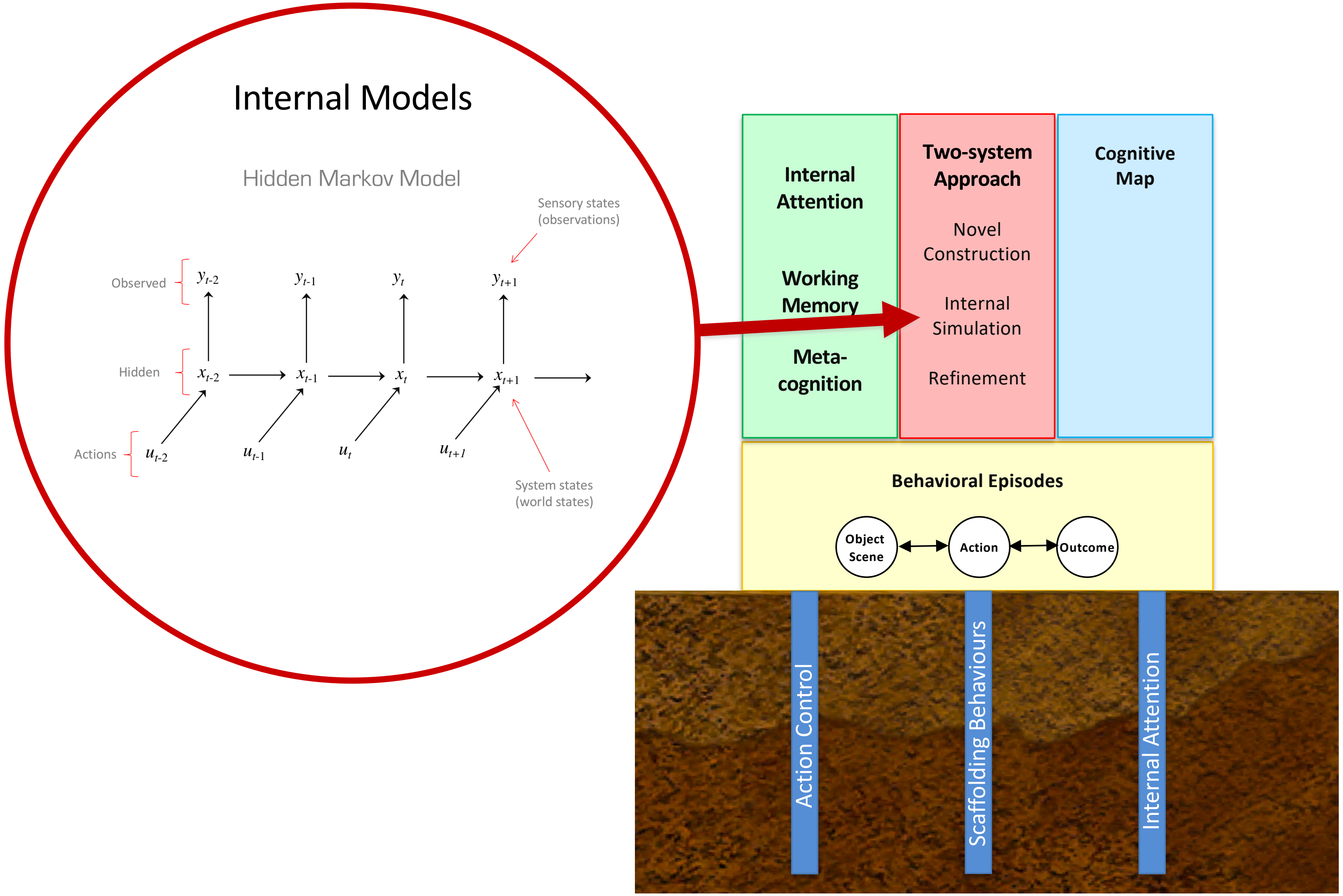
Situation Model Framework



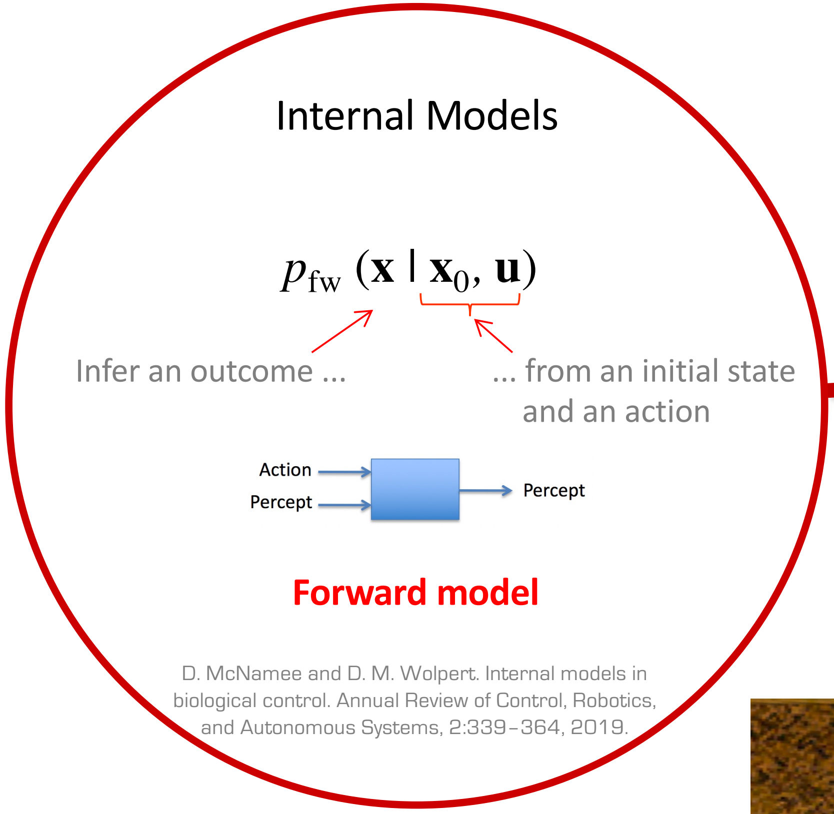
Situation Model Framework

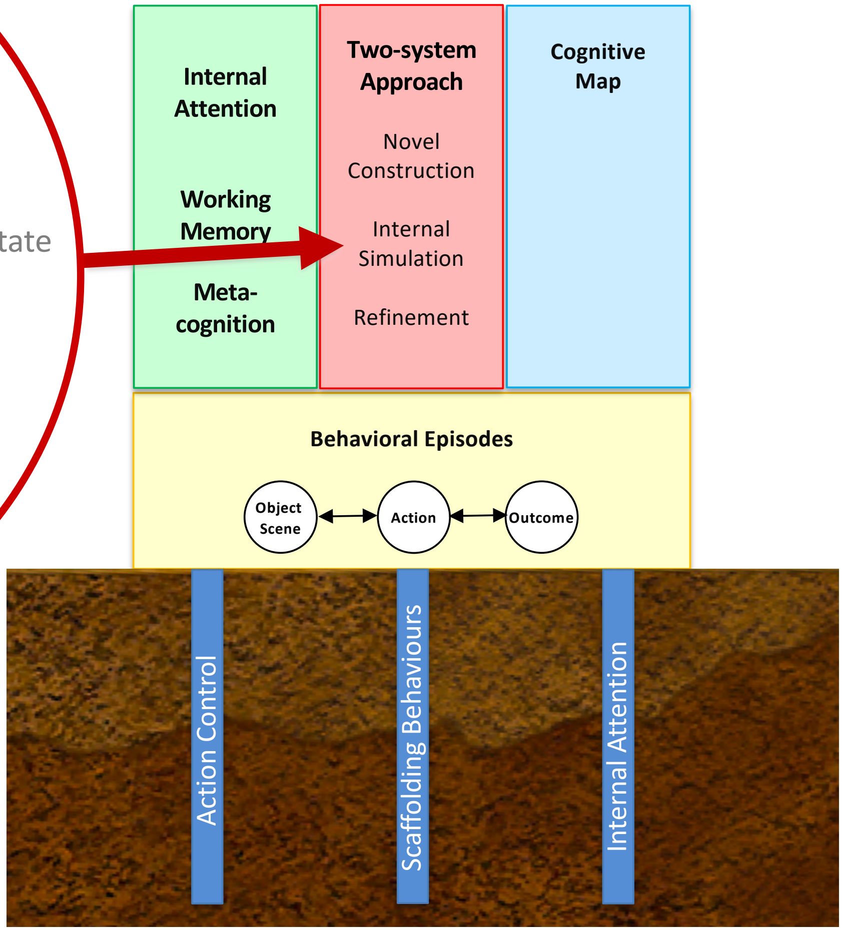


Situation Model Framework

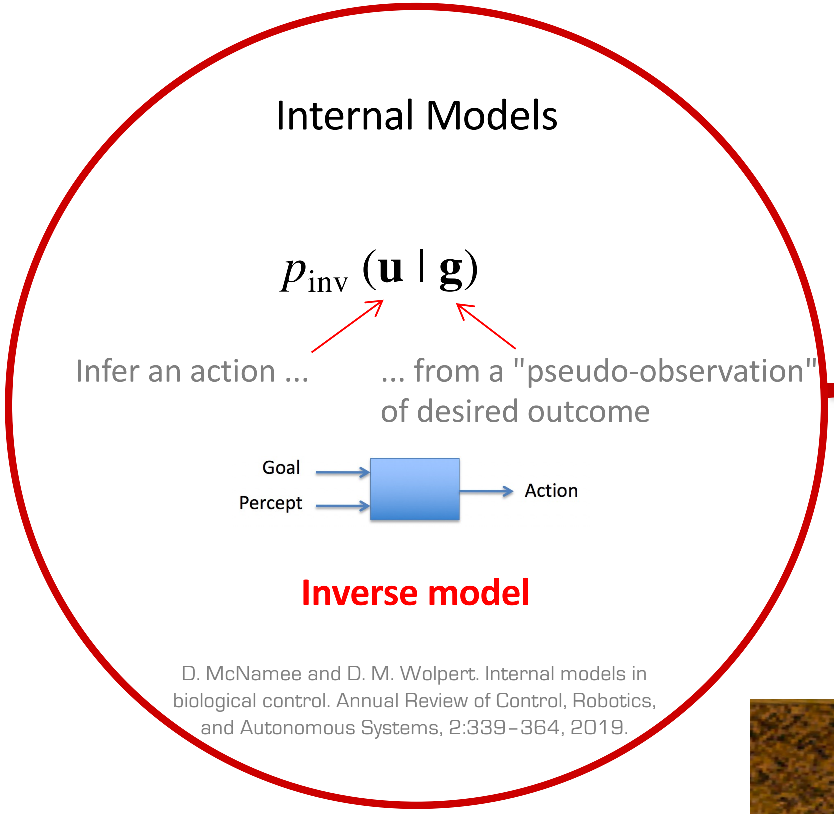


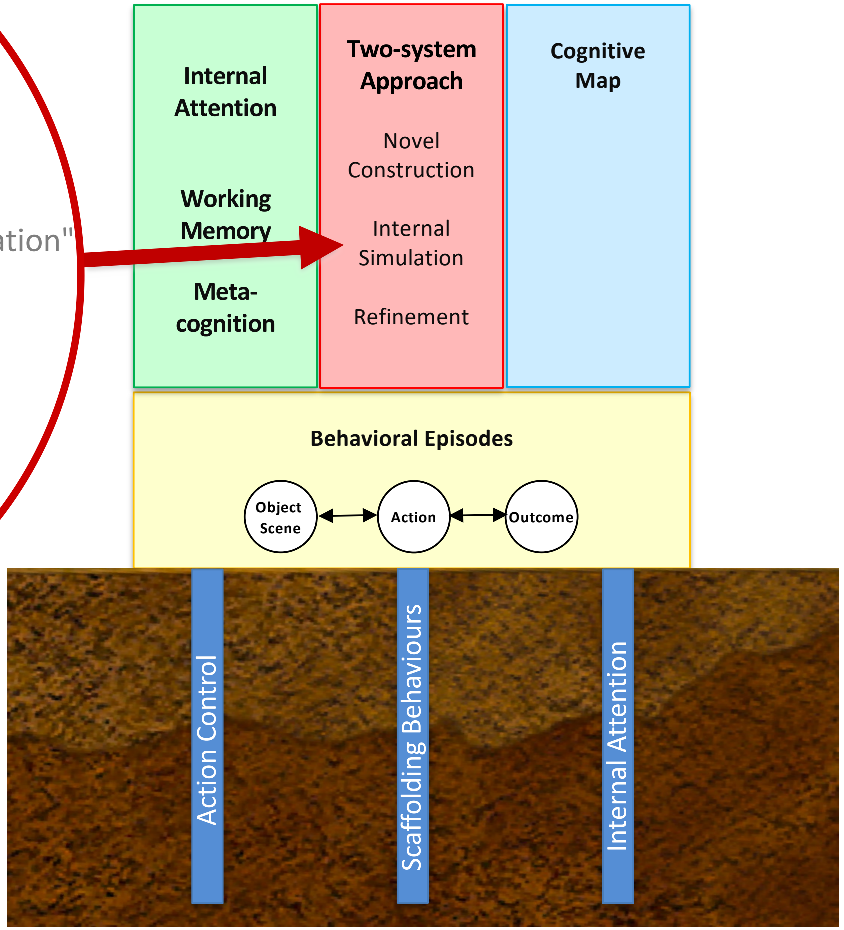
Situation Model Framework



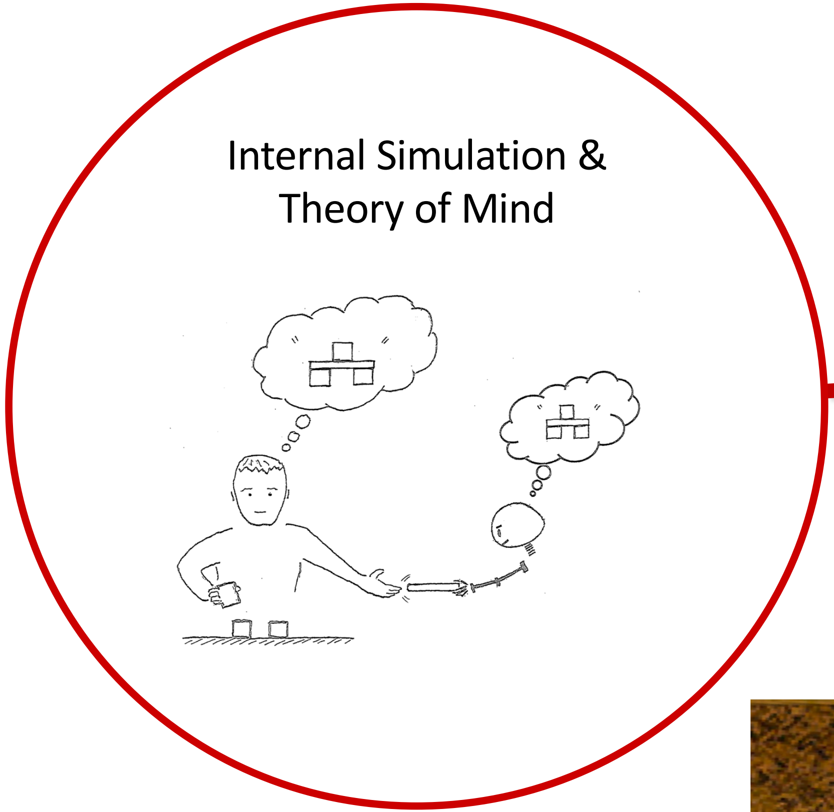


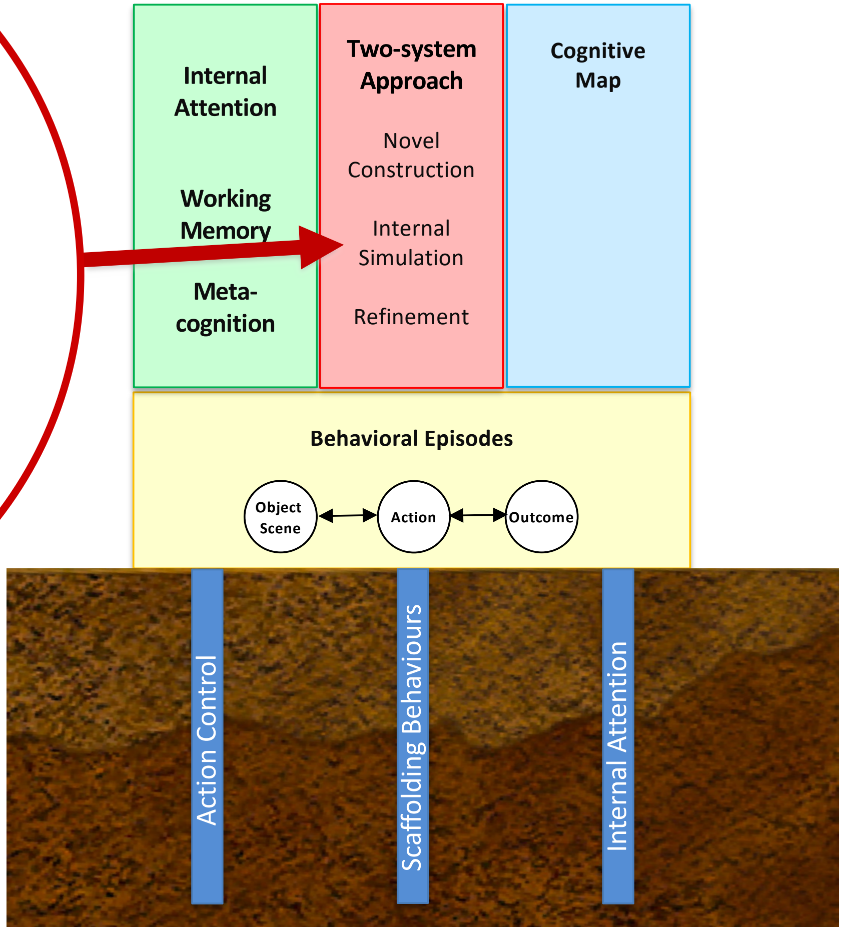
Situation Model Framework



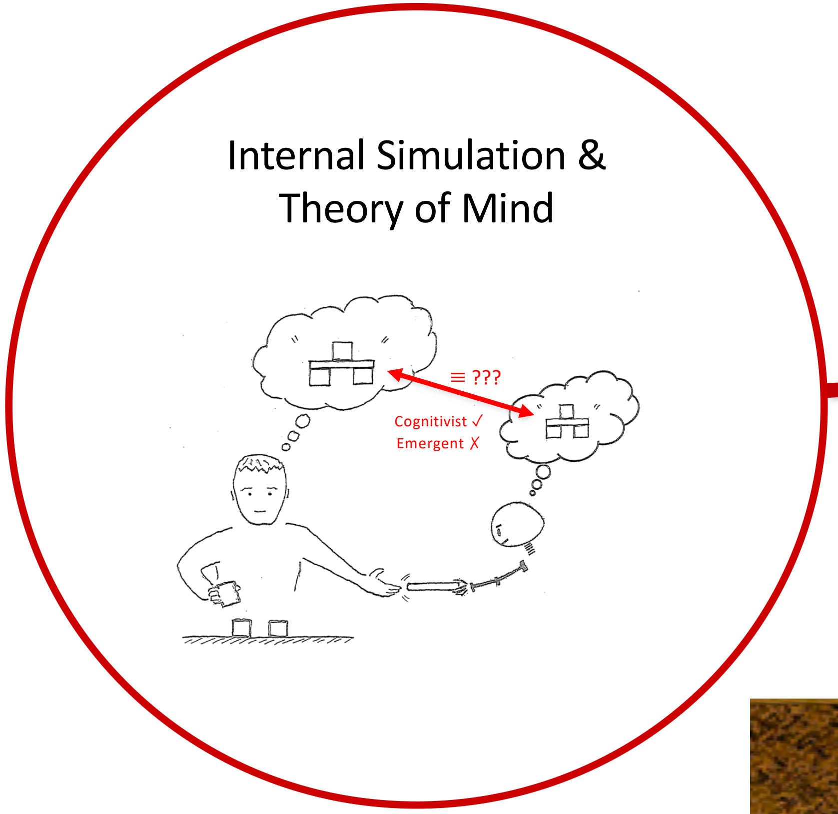


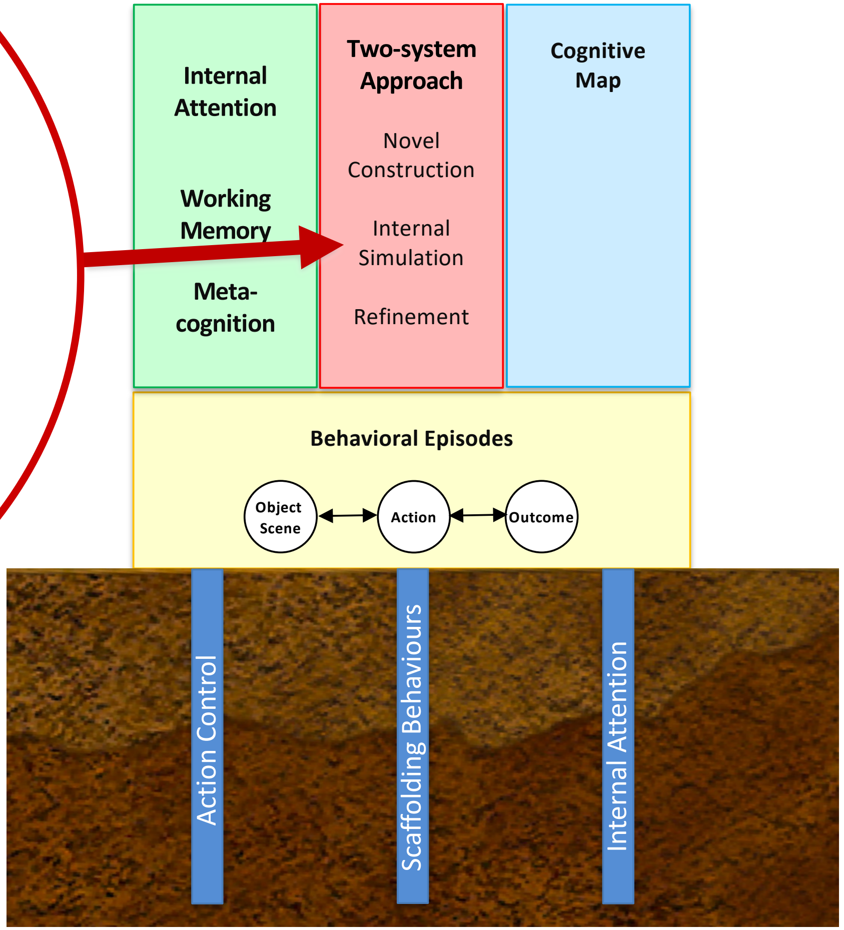
Situation Model Framework





Situation Model Framework



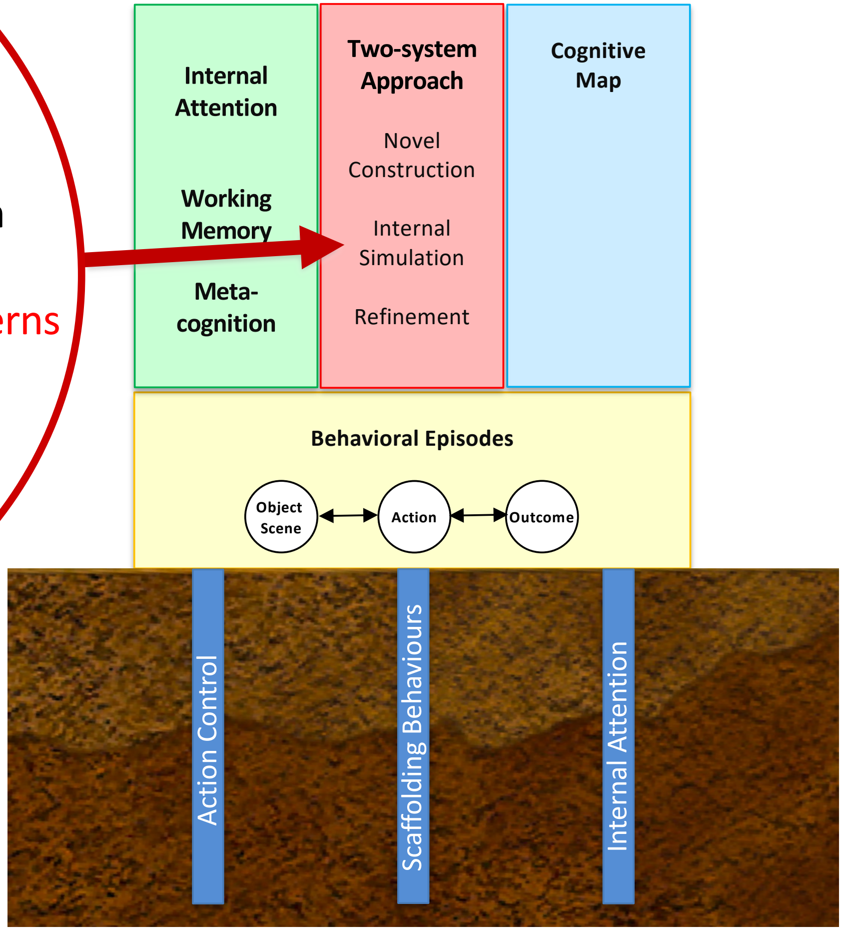


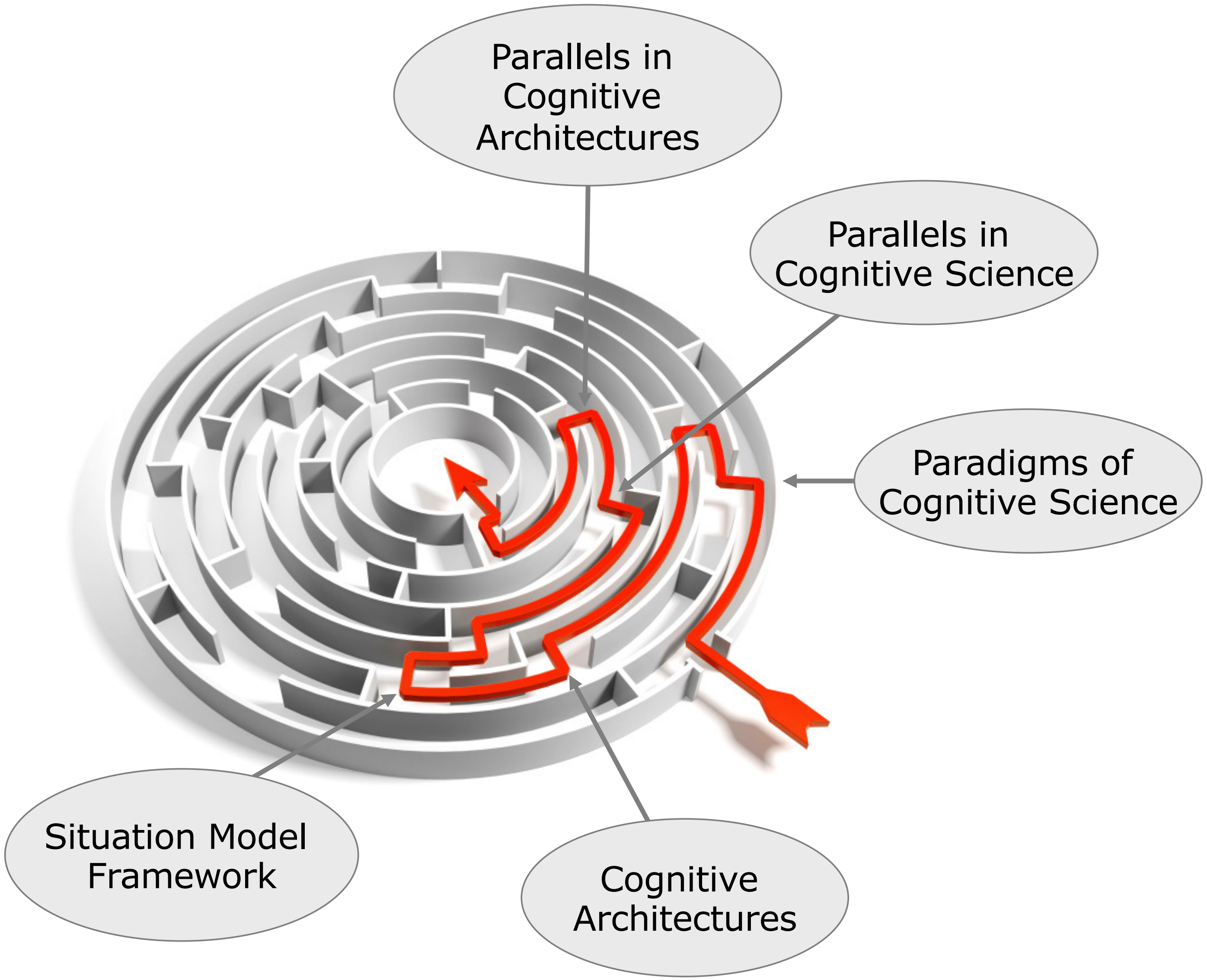
Situation Model Framework

Internal Simulation &
Doing Nothing

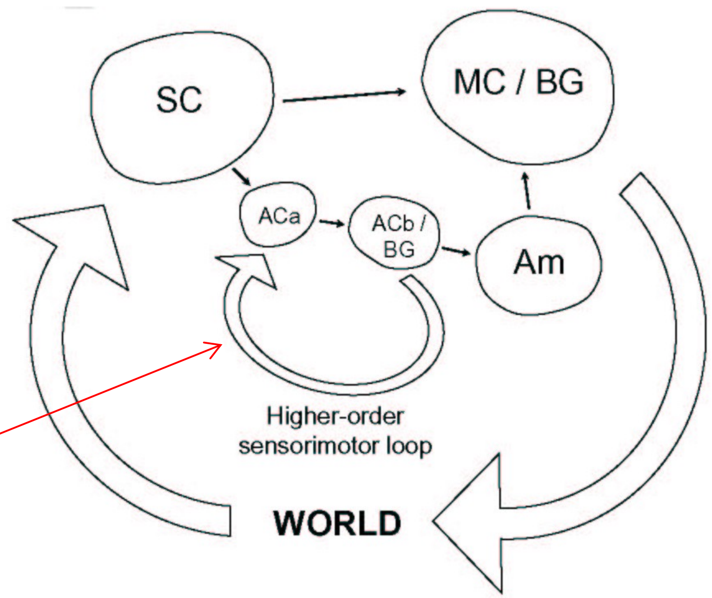
"the brain --- one's mind --- is automatically busy with extrapolation of future events and ... constructing alternative hypothetical behavioral patterns in order to be ready for what may happen next"

D. H. Ingvar. "Hyperfrontal distribution of the cerebal grey matter flow in resting wakefulness; on the functional autonomy of the conscious state". Acta Neurologica Scandinavica, 60(1):12–25, 1979.




Parallels in Cognitive Architectures
Parallels in Cognitive Science
Paradigms of Cognitive Science
Situation Model Framework
Cognitive Architectures

Global Workspace



Internal simulation

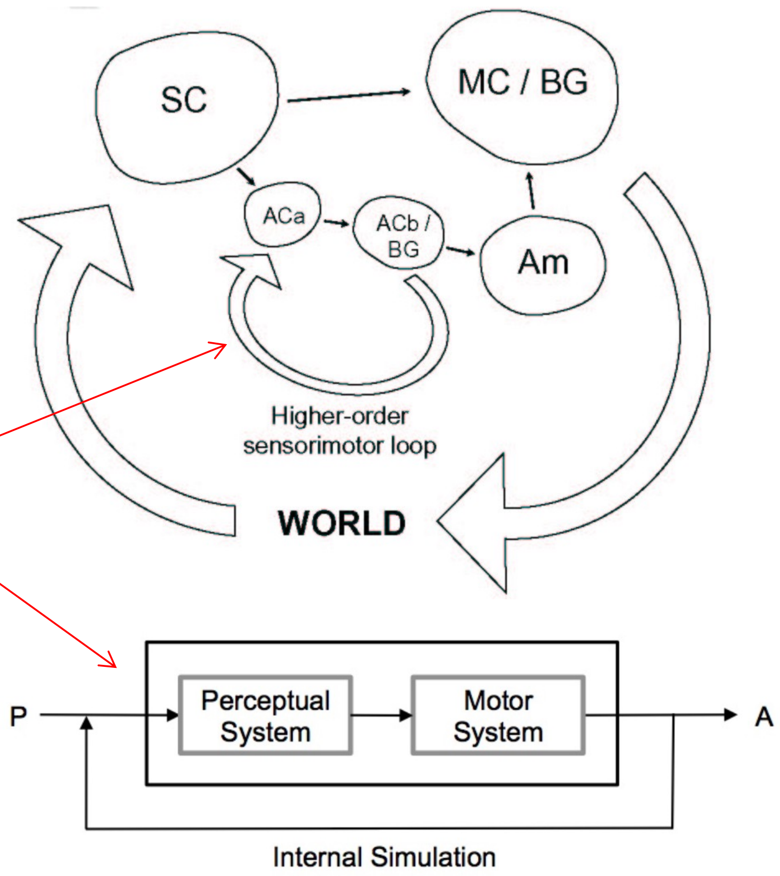
SC Sensory Cortex
MC Motor Cortex
BG Basal Ganglia (action selection)
AC Association Cortex
Am Amygdala (affect)

M. P. Shanahan. Cognition, action selection, and inner rehearsal. In Proceedings IJCAI Workshop on Modelling Natural Action Selection, pages 92–99, 2005.

M. P. Shanahan. A cognitive architecture that combines internal simulation with a global workspace. Consciousness and Cognition, 15:433–449, 2006.

Global Workspace

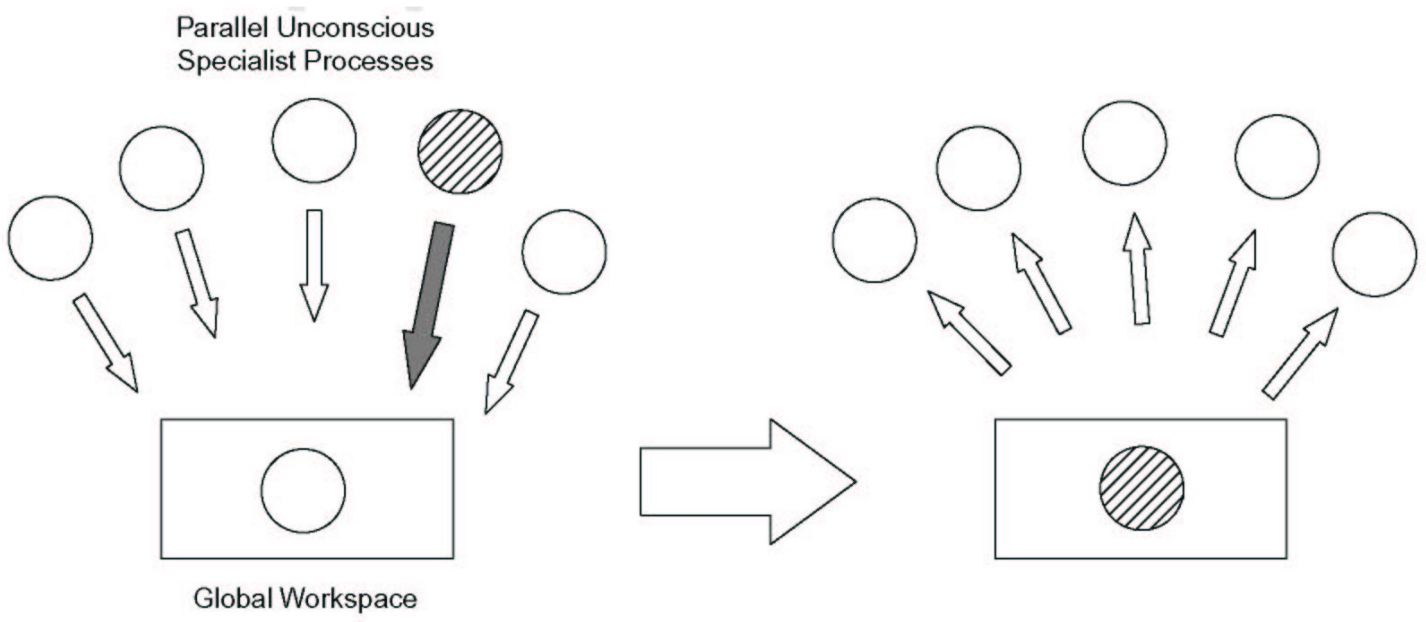
Internal simulation



SC Sensory Cortex
MC Motor Cortex
BG Basal Ganglia (action selection)
AC Association Cortex
Am Amygdala (affect)

Global Workspace

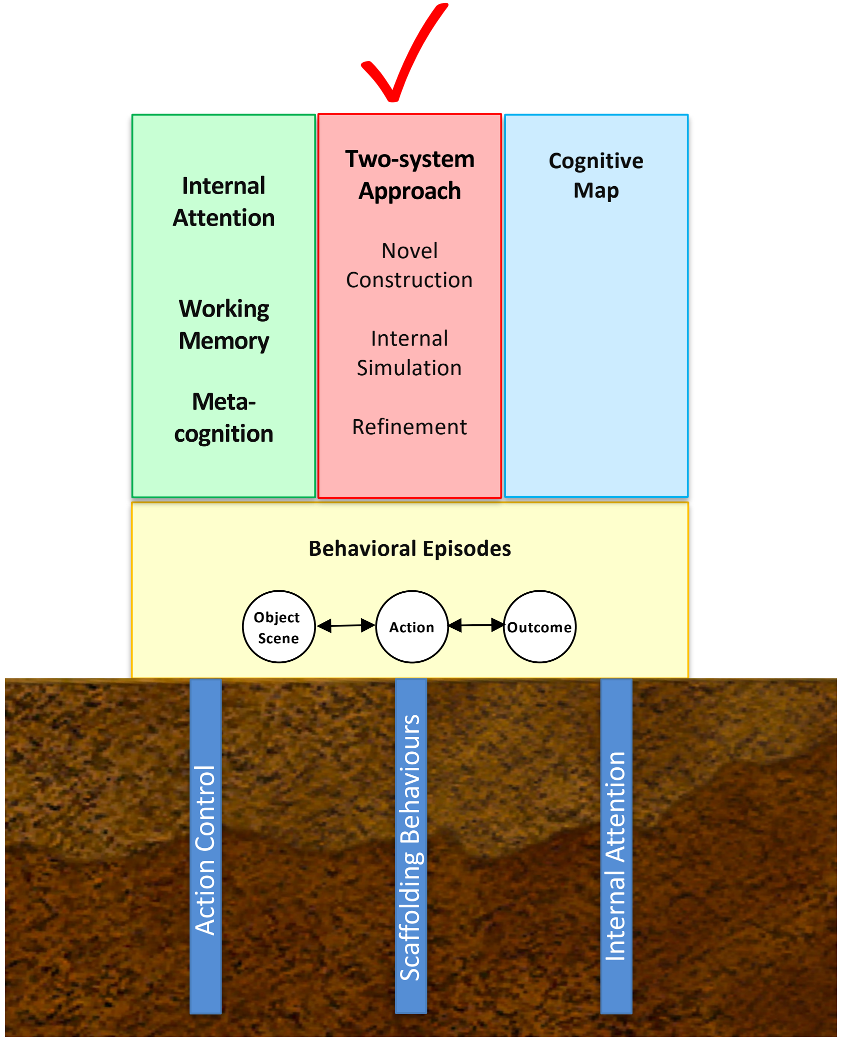
Global workspace model:
sequence of states emerge from multiple competing and cooperating parallel processes



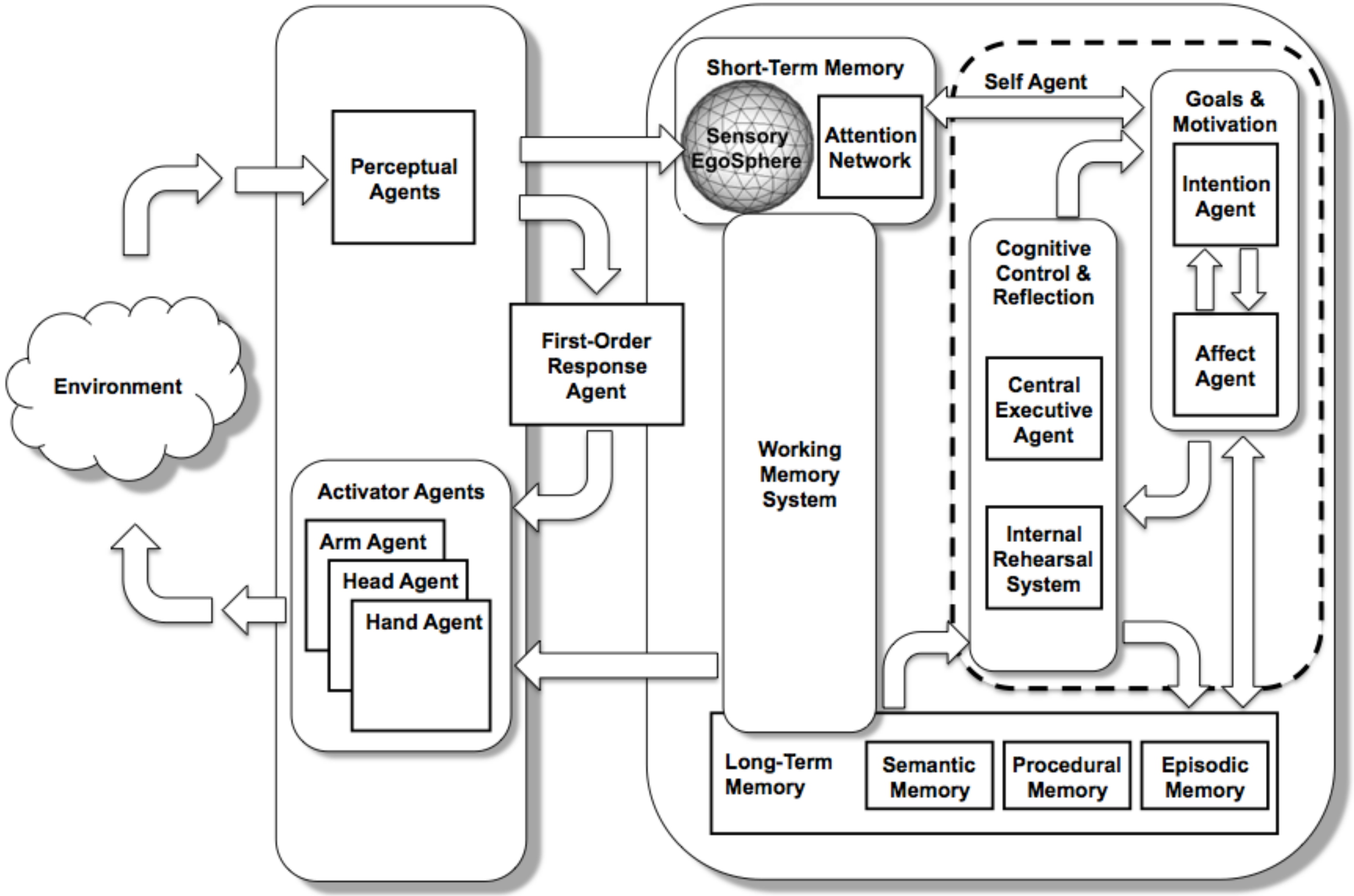
Global Workspace

Global workspace model:
sequence of states emerge from multiple competing and cooperating parallel processes

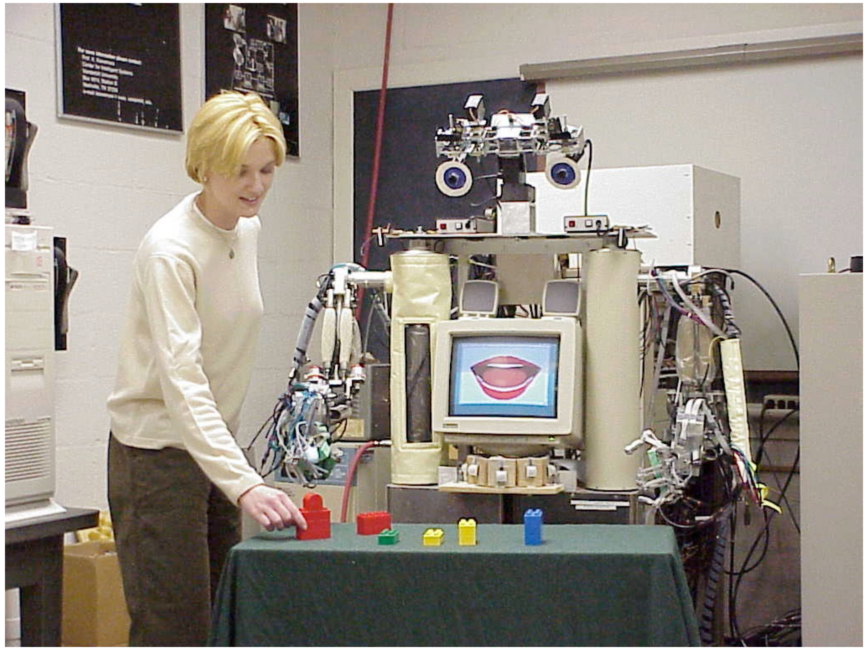
Situation Model Framework



ISAC

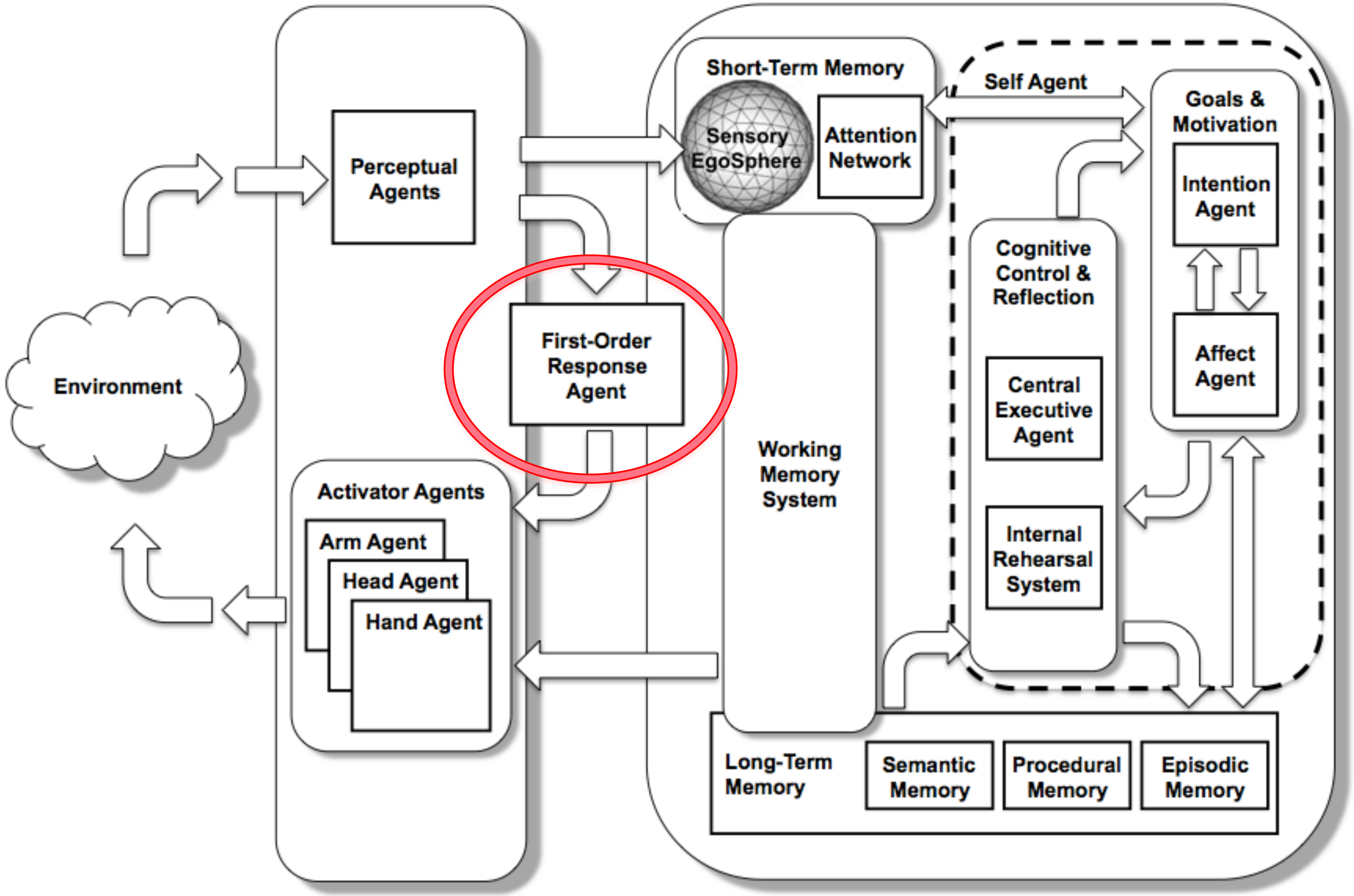

Environment
Perceptual Agents
First-Order Response Agent
Activator Agents
Arm Agent
Head Agent
Hand Agent
Short-Term Memory
Sensory EgoSphere
Attention Network
Working Memory System
Self Agent
Goals & Motivation
Intention Agent
Affect Agent
Cognitive Control & Reflection
Central Executive Agent
Internal Rehearsal System
Long-Term Memory
Semantic Memory
Procedural Memory
Episodic Memory

ISAC



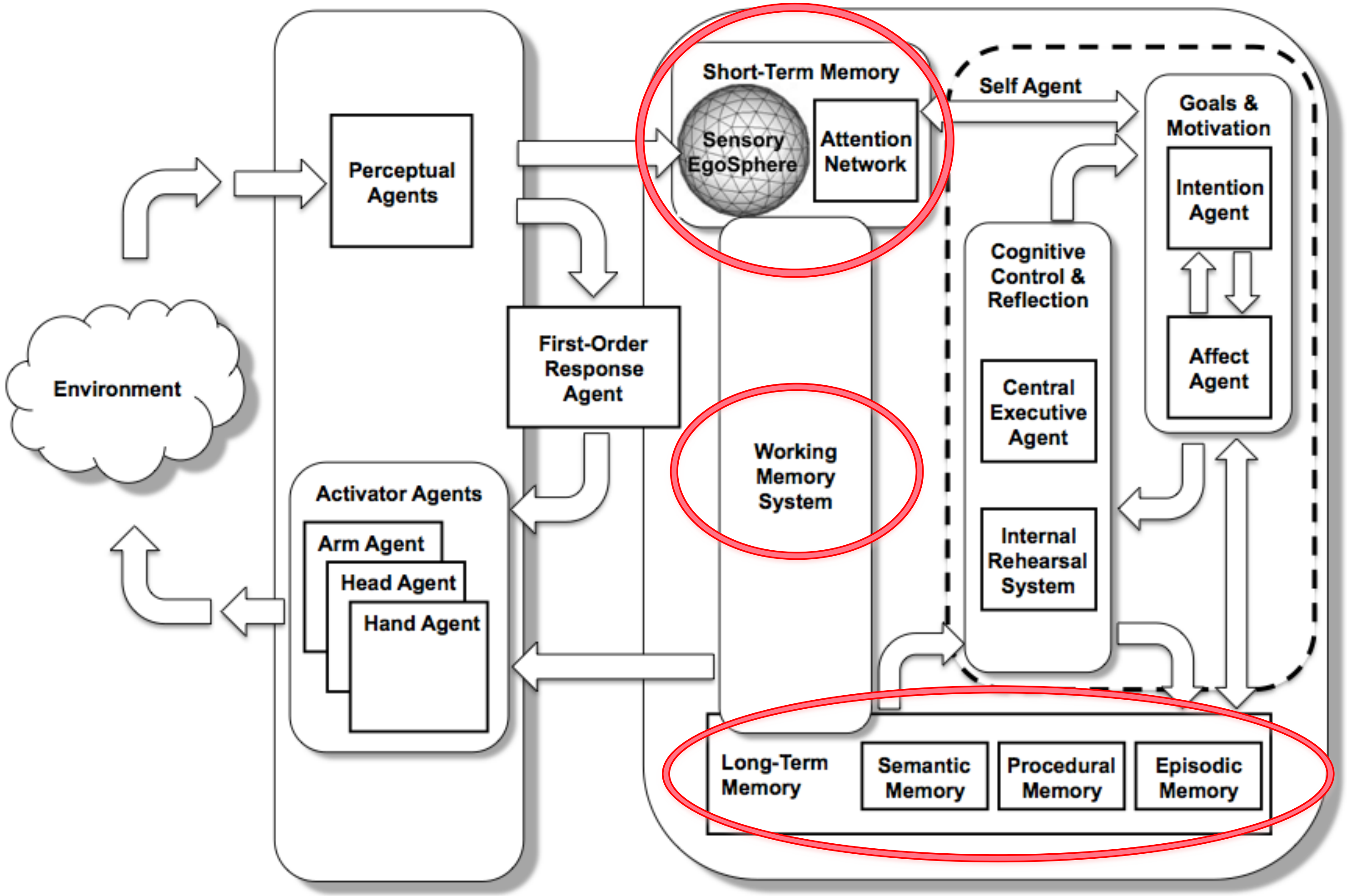
K. Kawamura, S. M. Gordon, P. Ratanaswasd, E. Erdemir, and J. F. Hall. Implementation of cognitive control for a humanoid robot. International Journal of Humanoid Robotics, 5(4):547–586, 2008.

ISAC



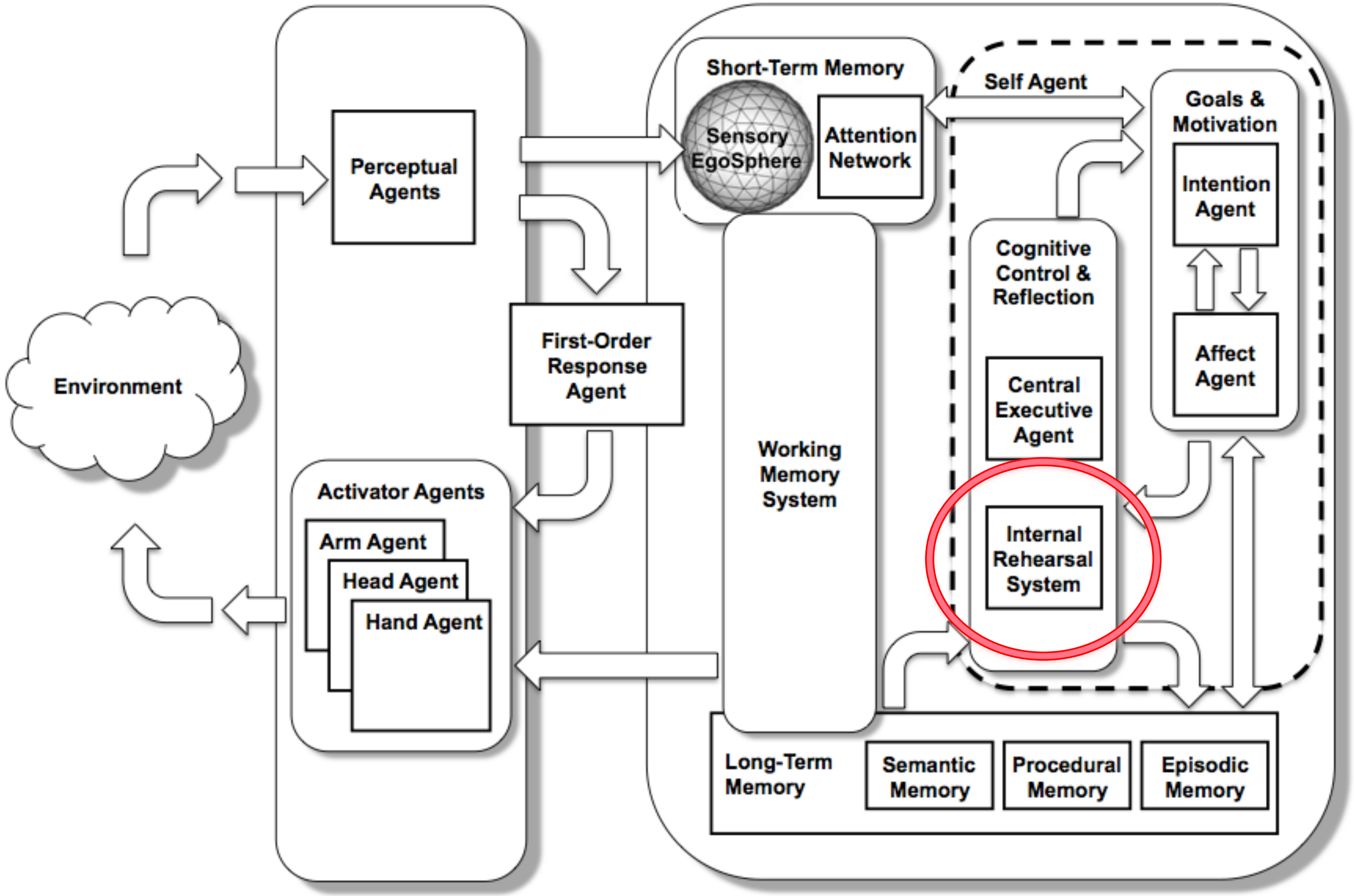
Perceptual Agents
Short-Term Memory
Sensory EgoSphere
Attention Network
Self Agent
Goals & Motivation
Intention Agent
Affect Agent
Cognitive Control & Reflection
Central Executive Agent
Internal Rehearsal System
Environment
First-Order Response Agent
Working Memory System
Activator Agents
Arm Agent
Head Agent
Hand Agent
Long-Term Memory
Semantic Memory
Procedural Memory
Episodic Memory

ISAC



Environment
Perceptual Agents
First-Order Response Agent
Activator Agents
Arm Agent
Head Agent
Hand Agent
Short-Term Memory
Sensory EgoSphere
Attention Network
Working Memory System
Self Agent
Goals & Motivation
Intention Agent
Affect Agent
Cognitive Control & Reflection
Central Executive Agent
Internal Rehearsal System
Long-Term Memory
Semantic Memory
Procedural Memory
Episodic Memory

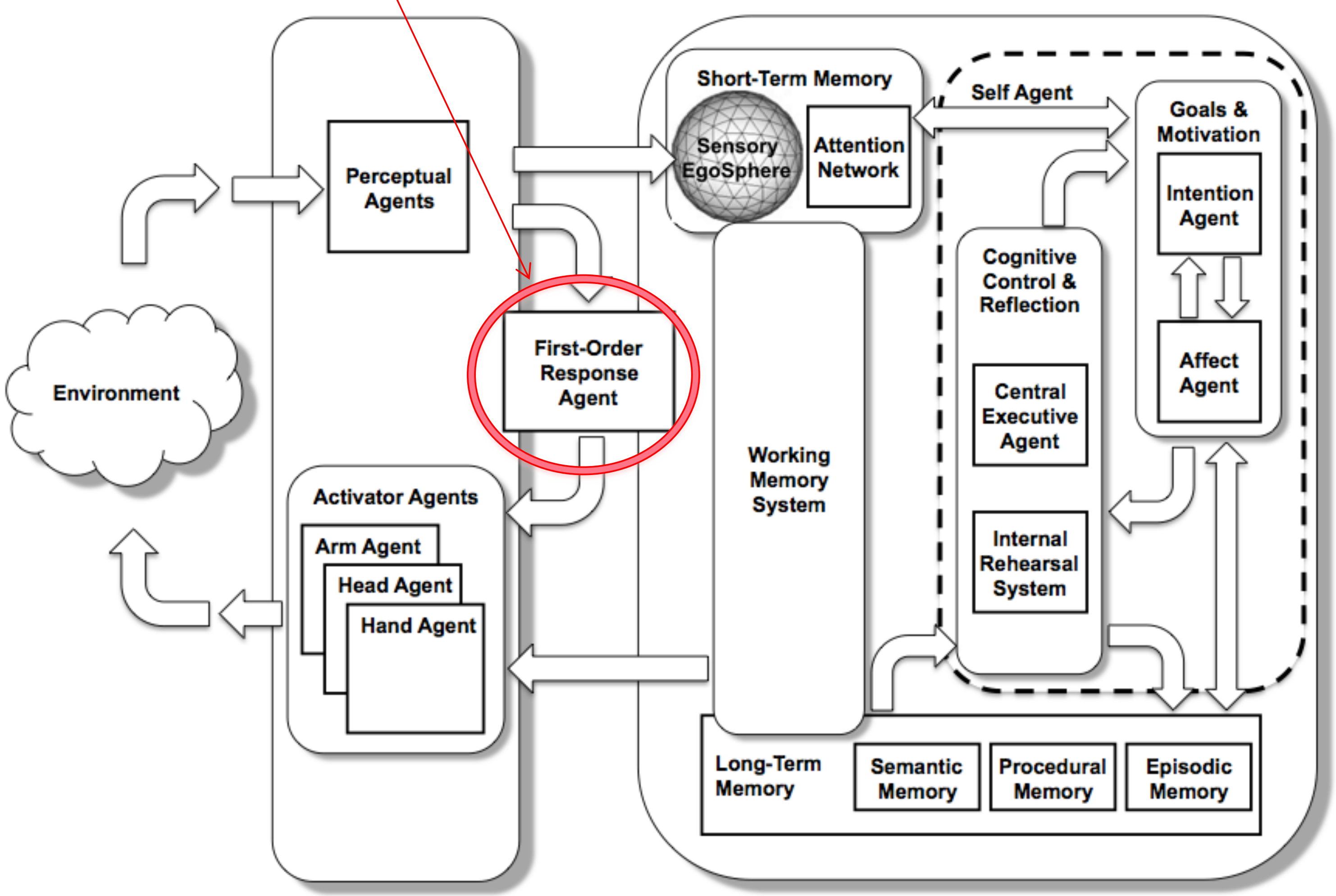
ISAC



Environment
Perceptual Agents
First-Order Response Agent
Activator Agents
Arm Agent
Head Agent
Hand Agent
Short-Term Memory
Sensory EgoSphere
Attention Network
Working Memory System
Self Agent
Goals & Motivation
Intention Agent
Affect Agent
Cognitive Control & Reflection
Central Executive Agent
Internal Rehearsal System
Long-Term Memory
Semantic Memory
Procedural Memory
Episodic Memory

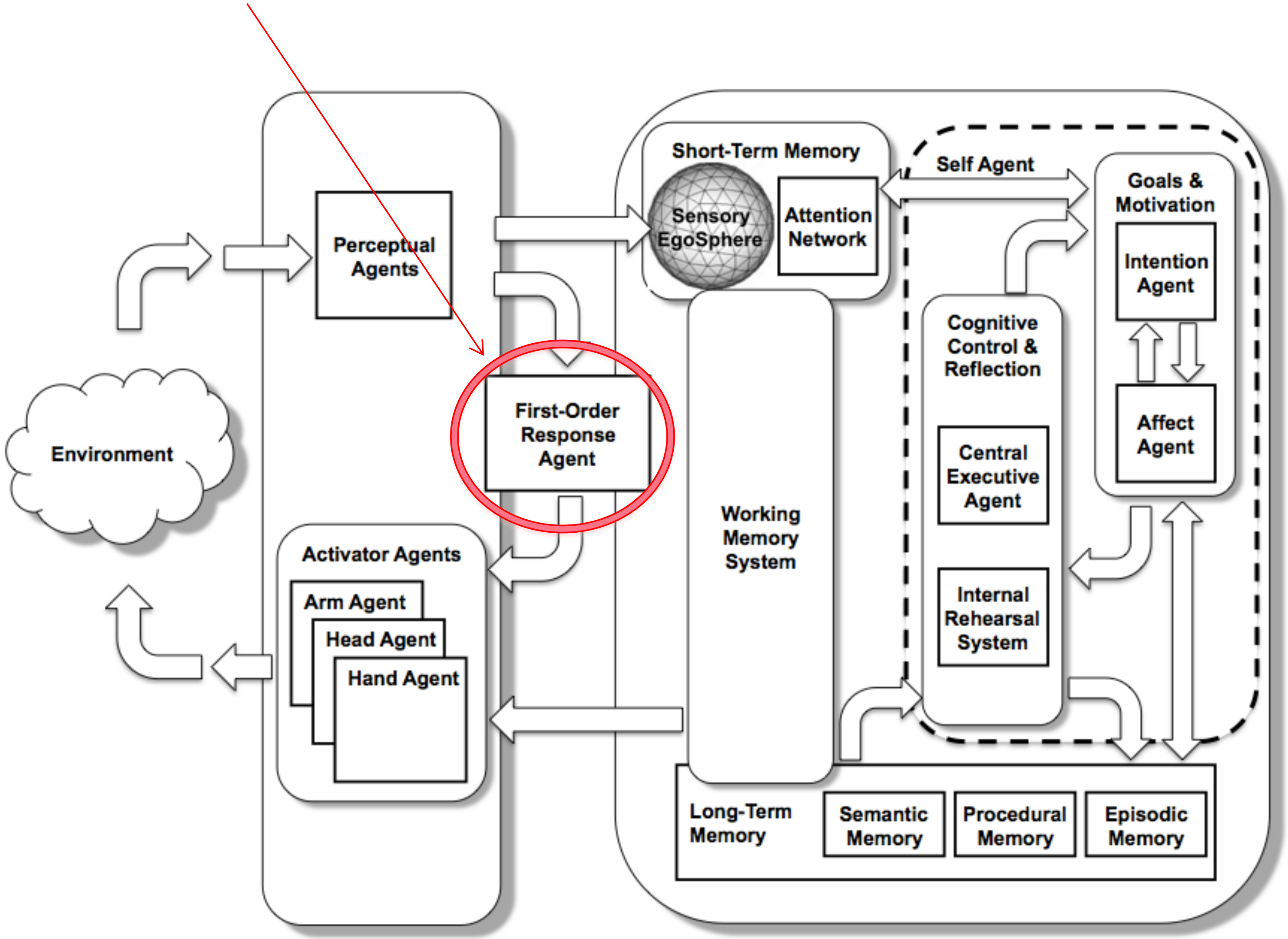
Normally, the First-order Response Agent (FRA) produces reactive responses to sensory triggers

ISAC



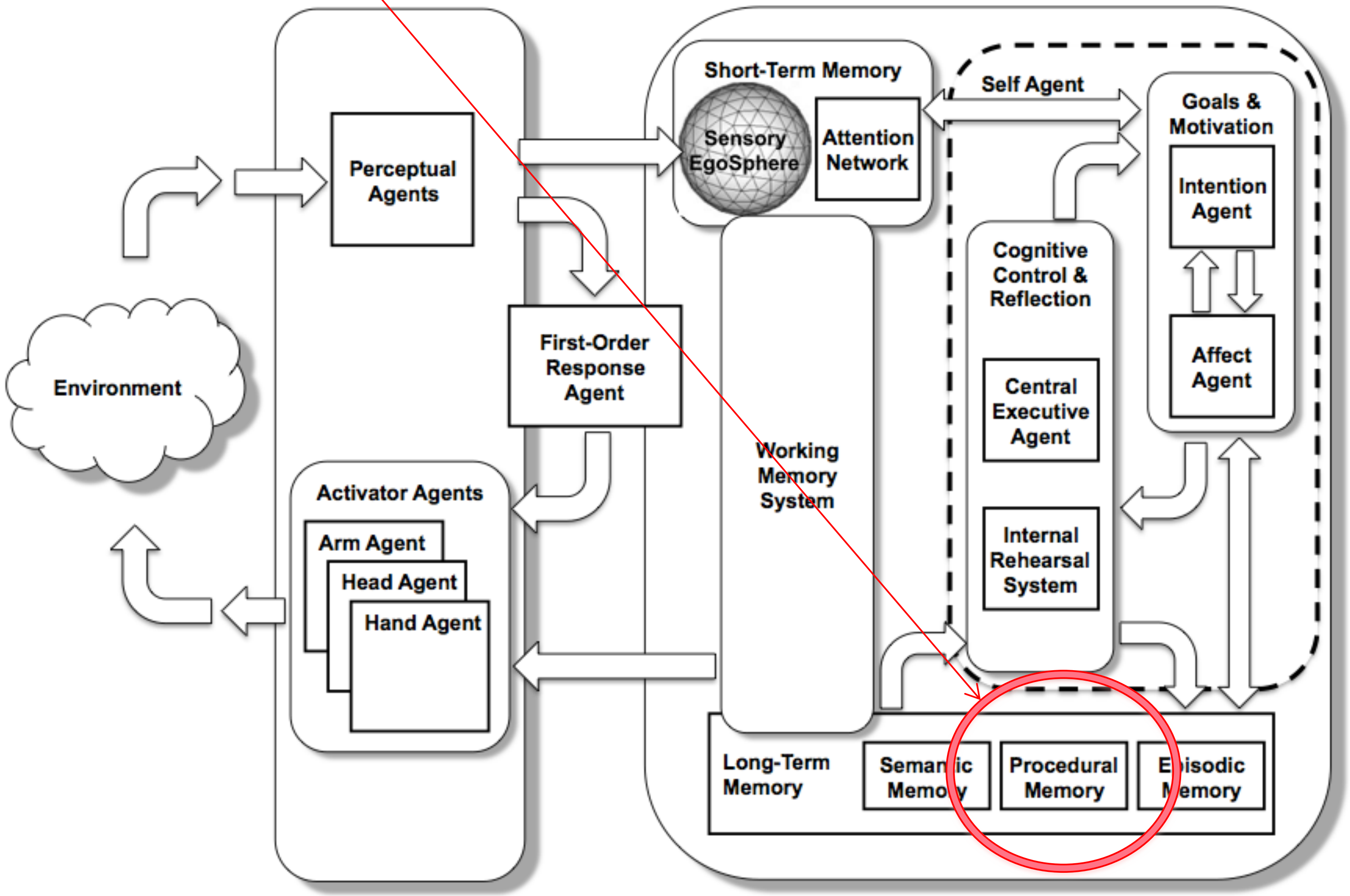
First-order Response Agent (FRA)
is also responsible for executing tasks

ISAC



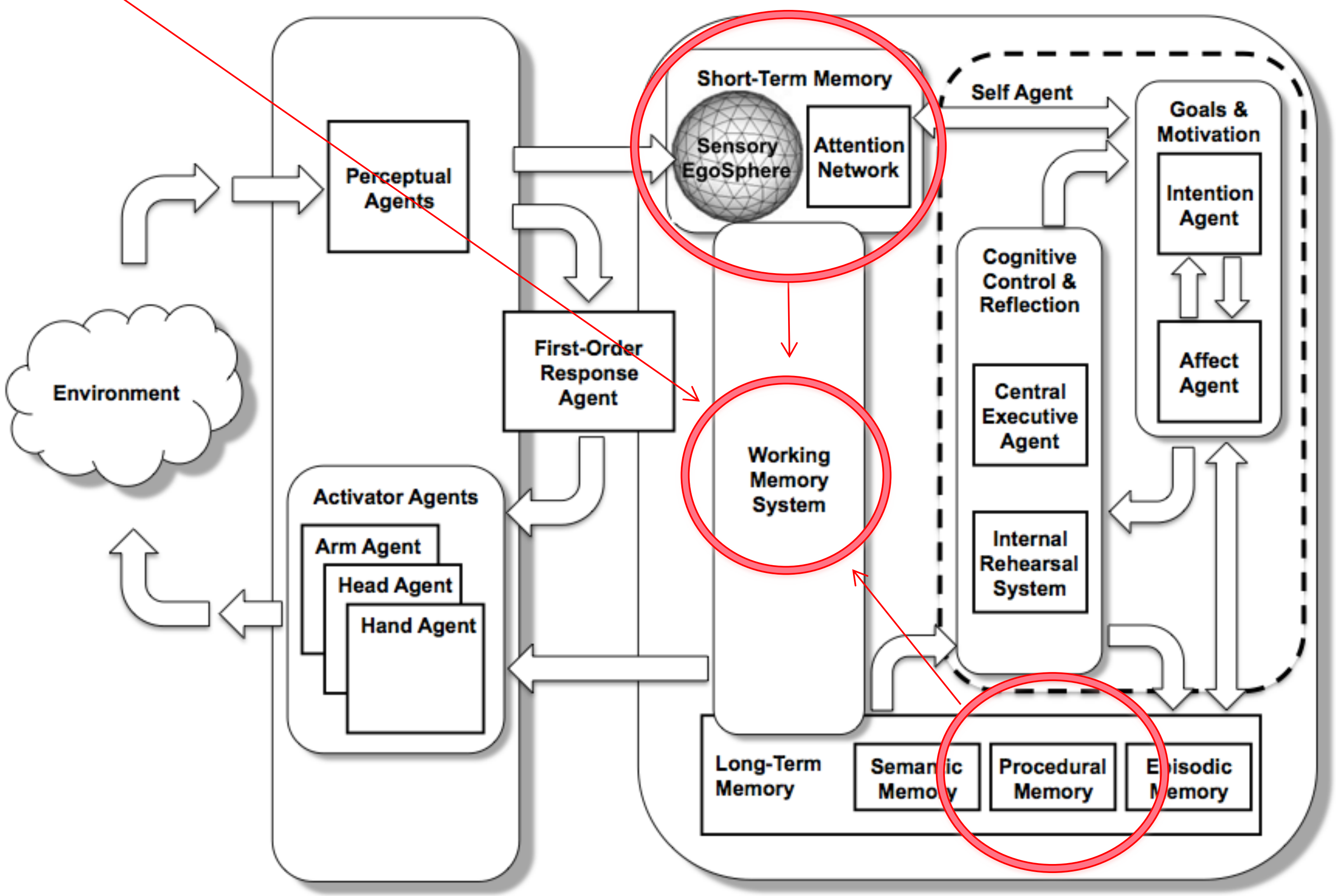
When a task is assigned by a human,
the FRA retrieves the skill from procedural memory
in LTM that corresponds to the skill described in the
task information

ISAC



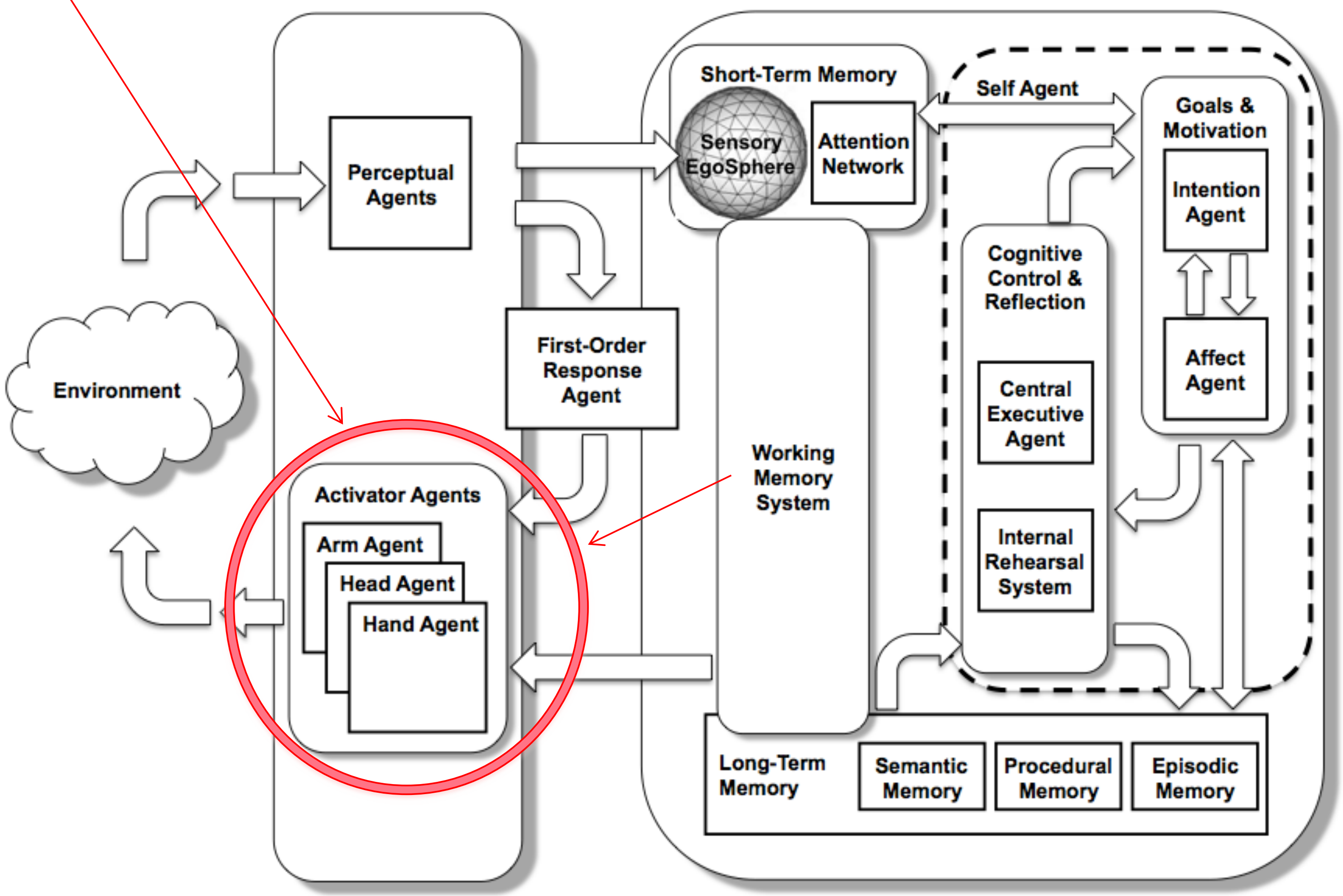
It then places it in the WMS as chunks along with the current percept

ISAC



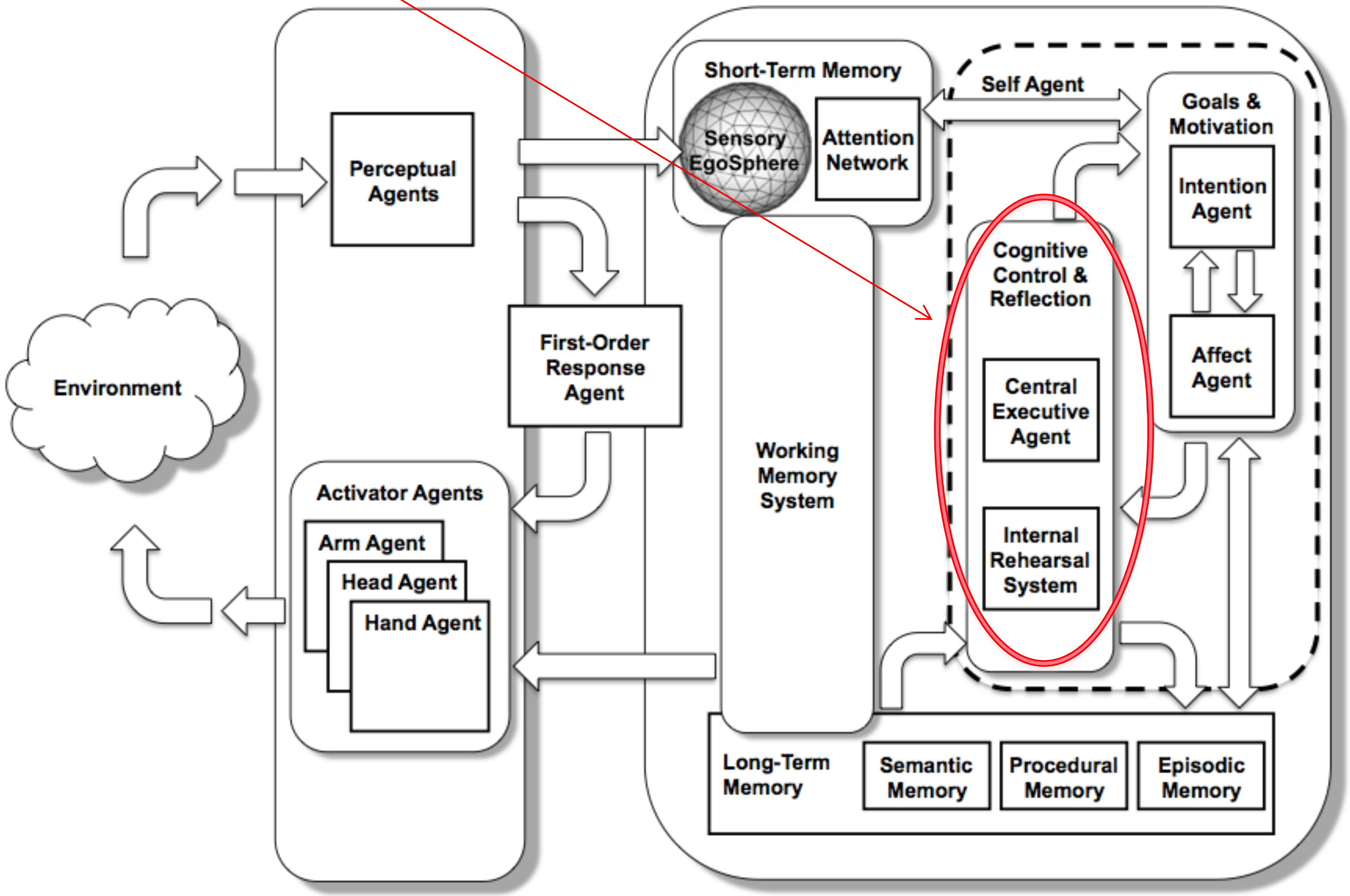
The Activator Agent then executes it, suspending execution whenever a reactive response is required

ISAC



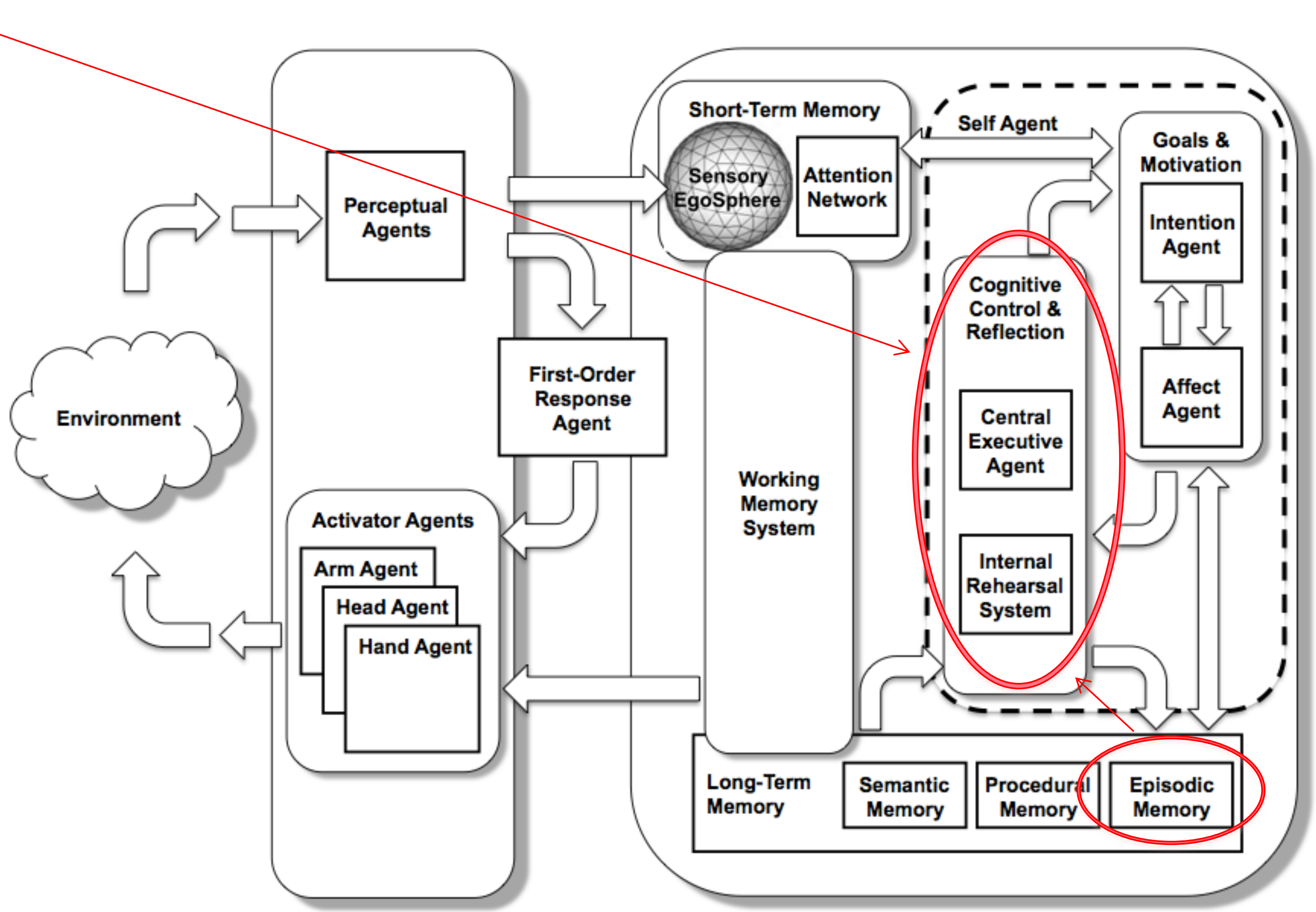
If the FRA finds no matching skill for the task, the Central Executive Agent takes over

ISAC



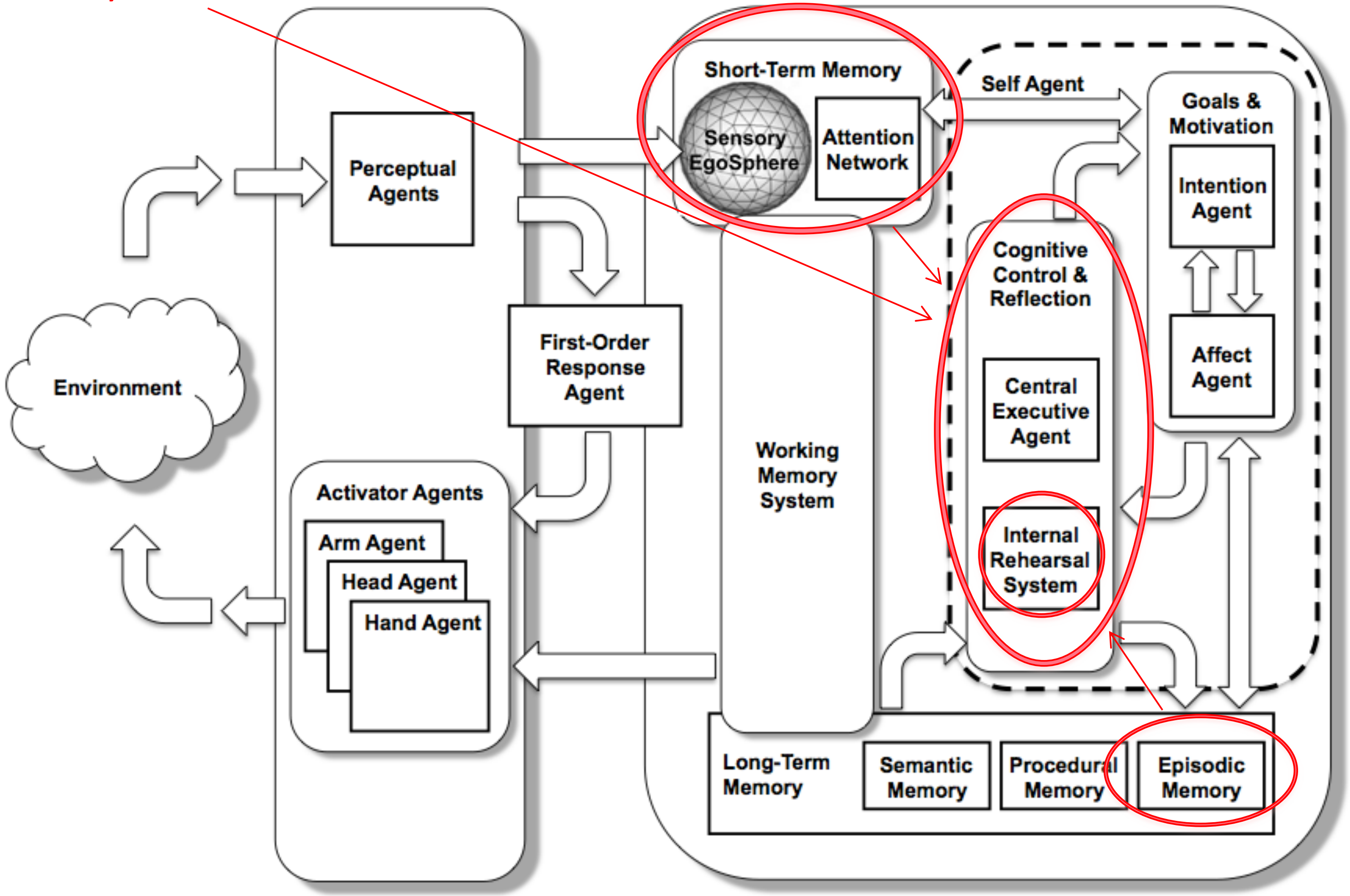
Recalls from episodic memory past experiences and behaviours that contain information similar to the current task

ISAC



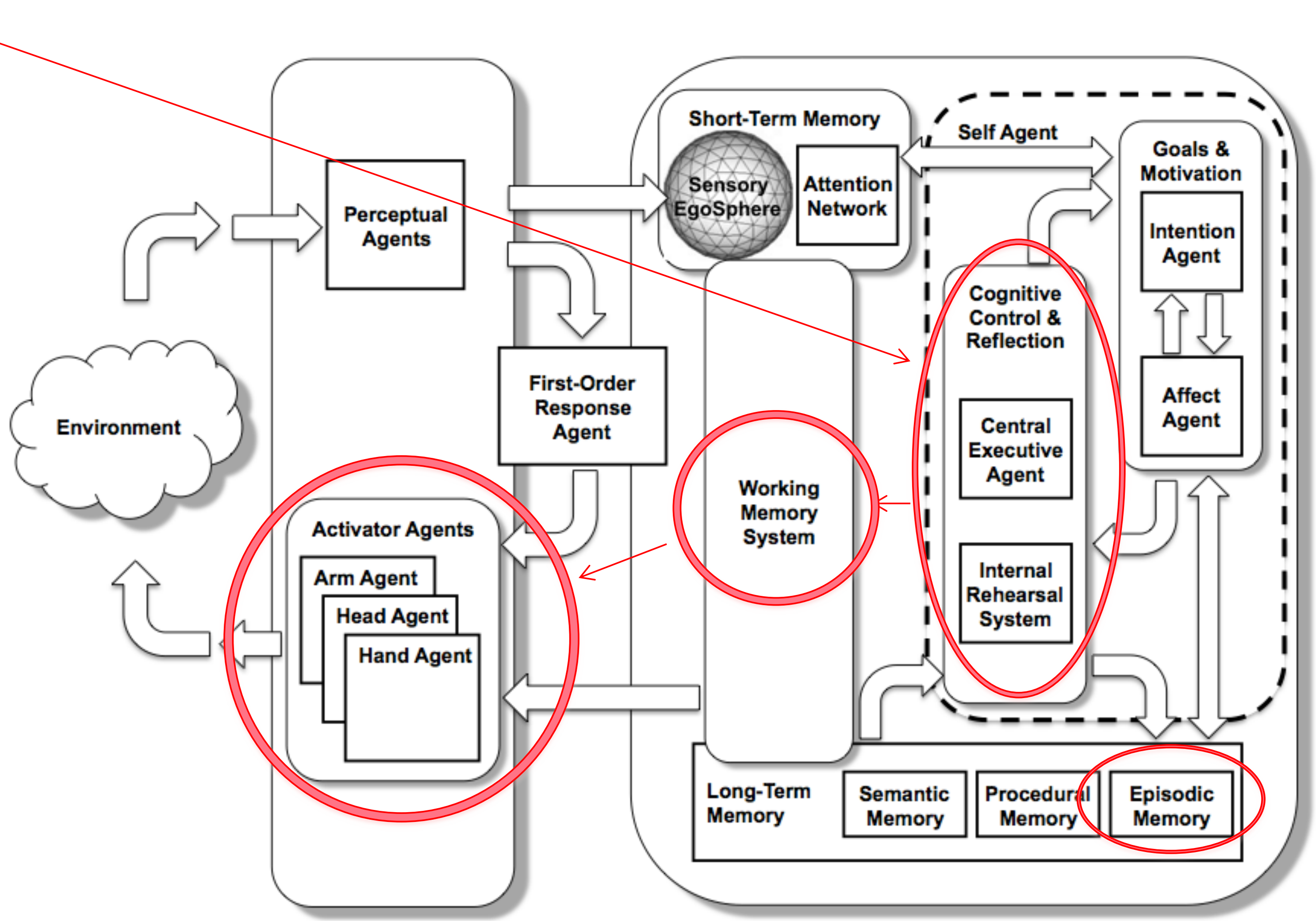
Select a behaviour-percept pair,
based on the current percept in the SES,
its relevance, and the likelihood of successful
execution as determined by internal simulation

ISAC

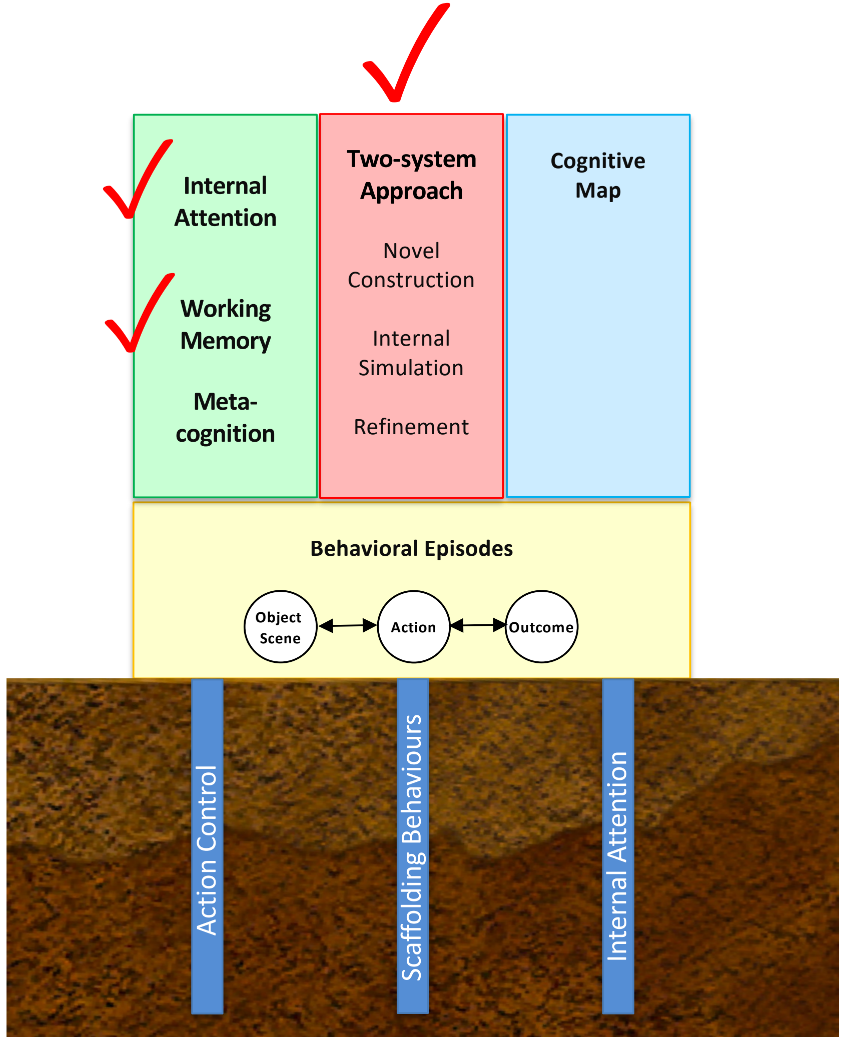


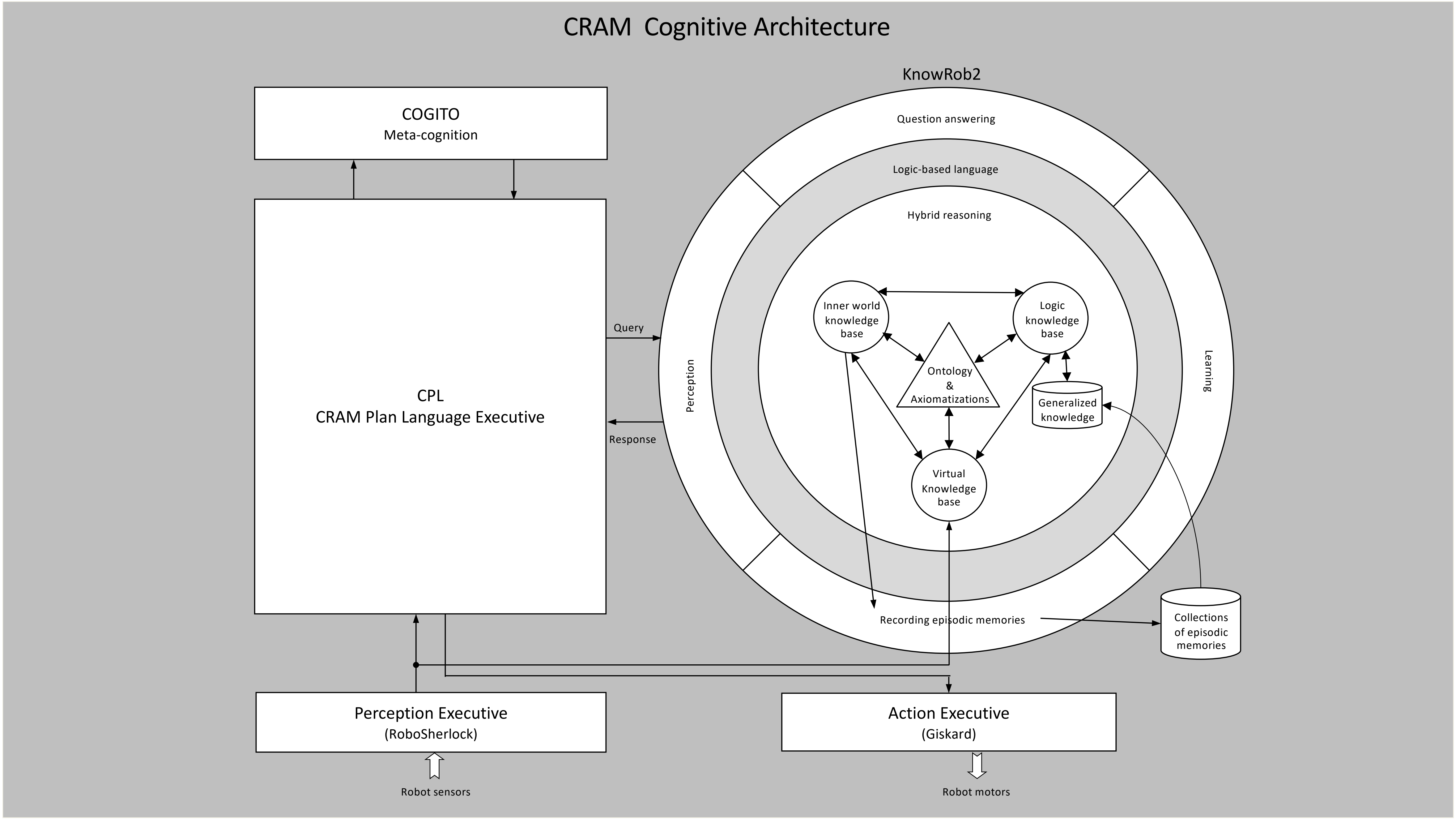
This is then placed in working memory and the Activator Agent executes the action

ISAC

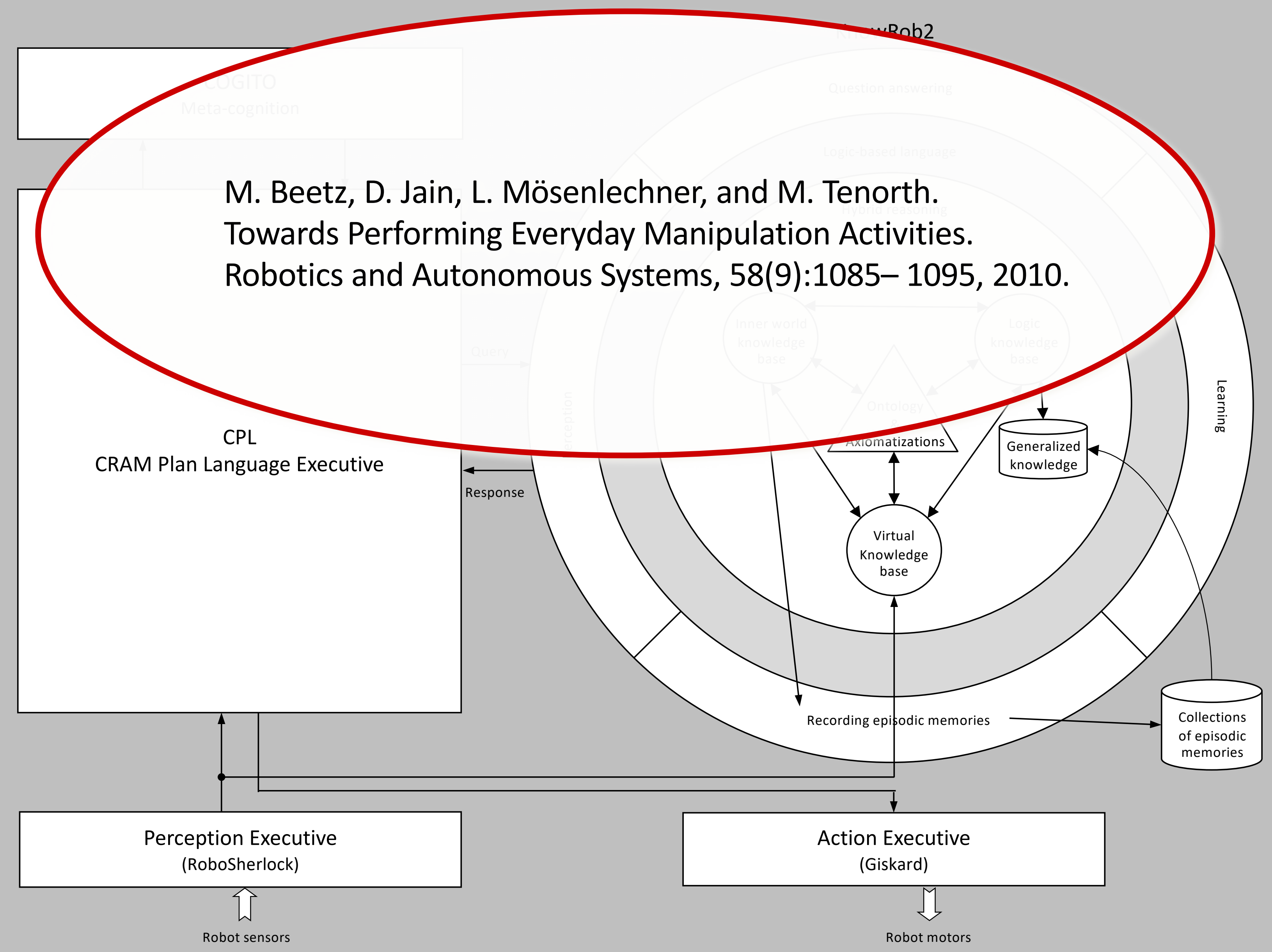


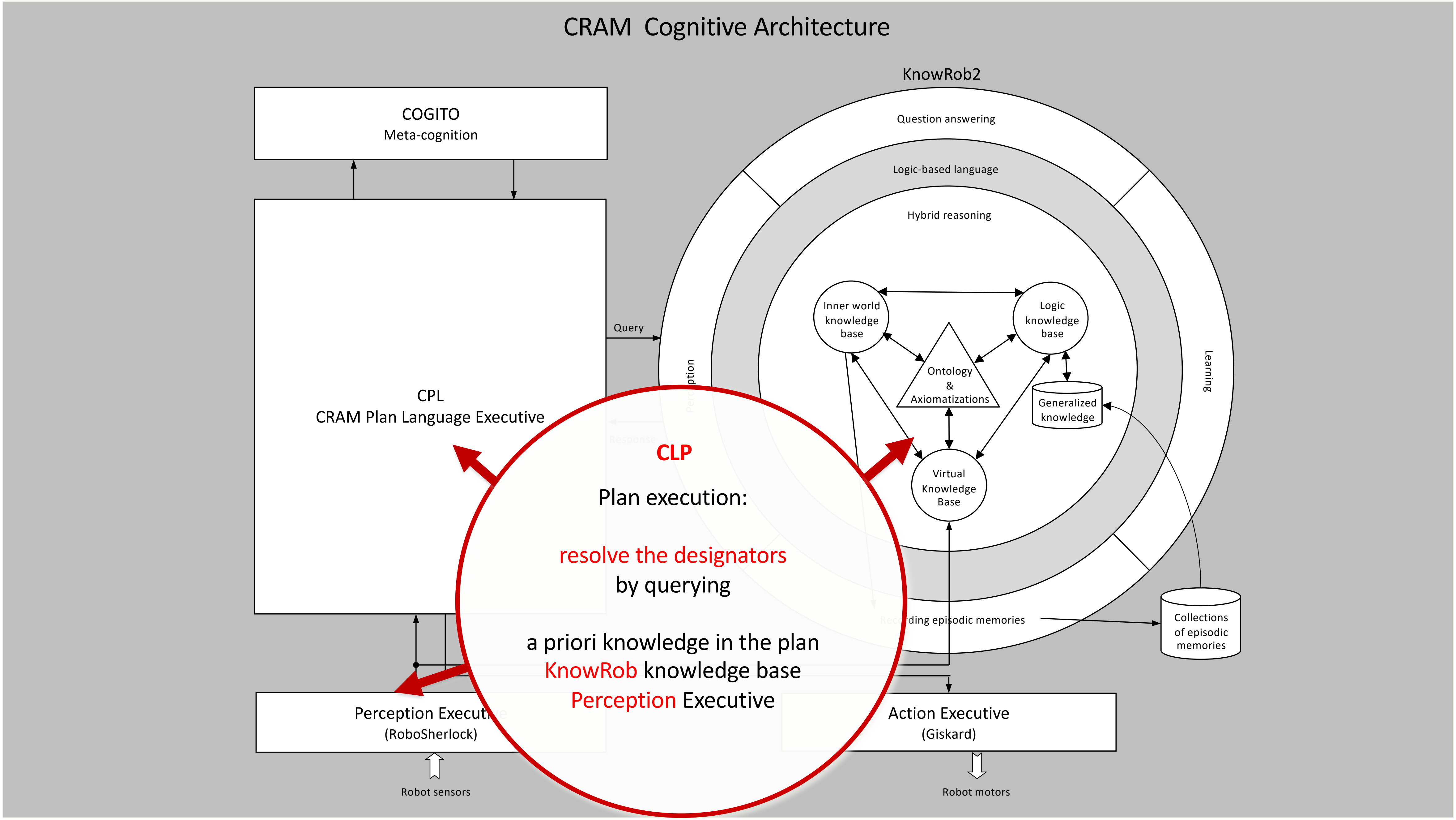
Situation Model Framework



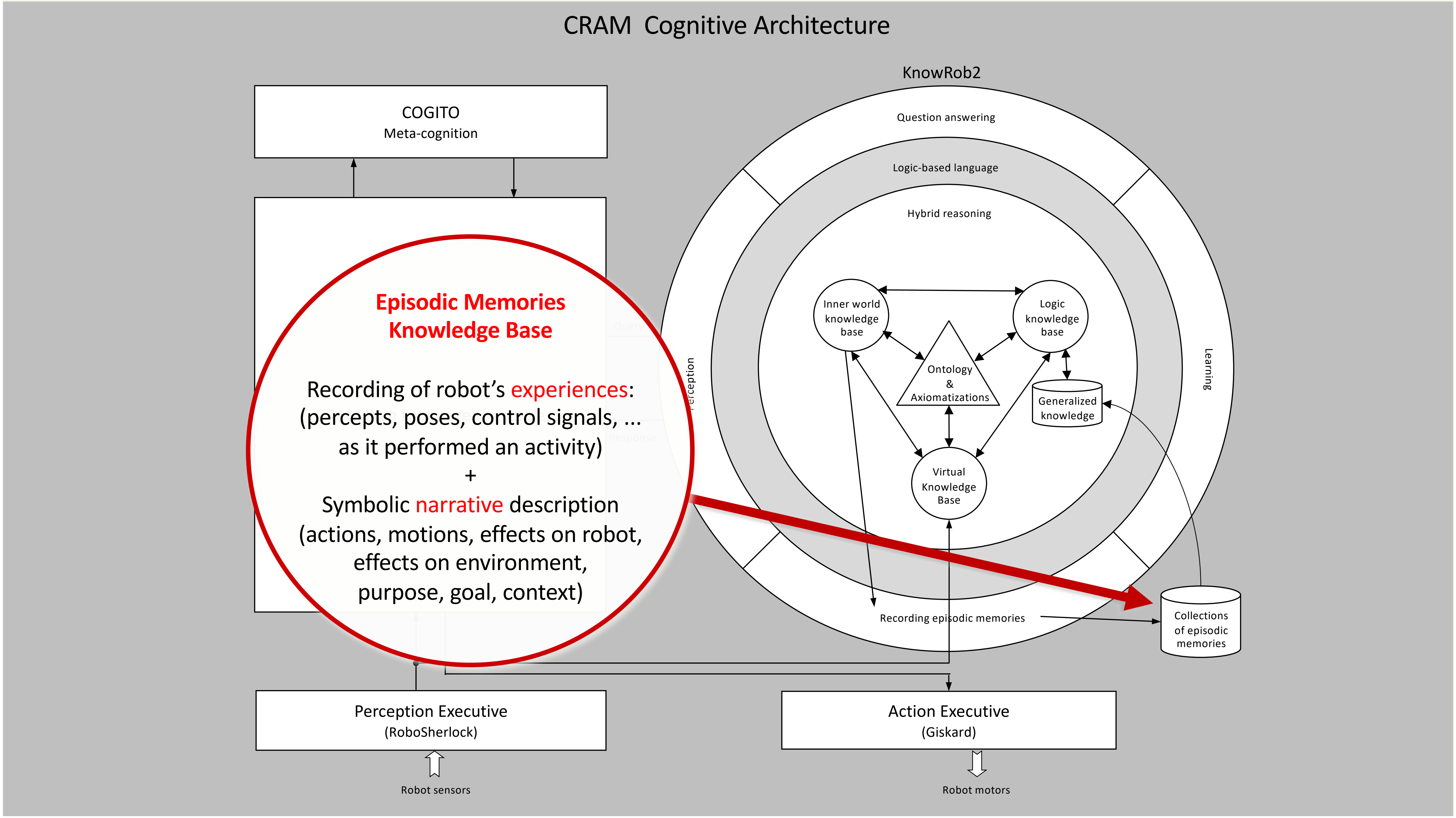

CRAM Cognitive Architecture
KnowRob2
COGITO
Meta-cognition
CPL
CRAM Plan Language Executive
Query
Response
Question answering
Logic-based language
Hybrid reasoning
Perception
Learning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge base
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors

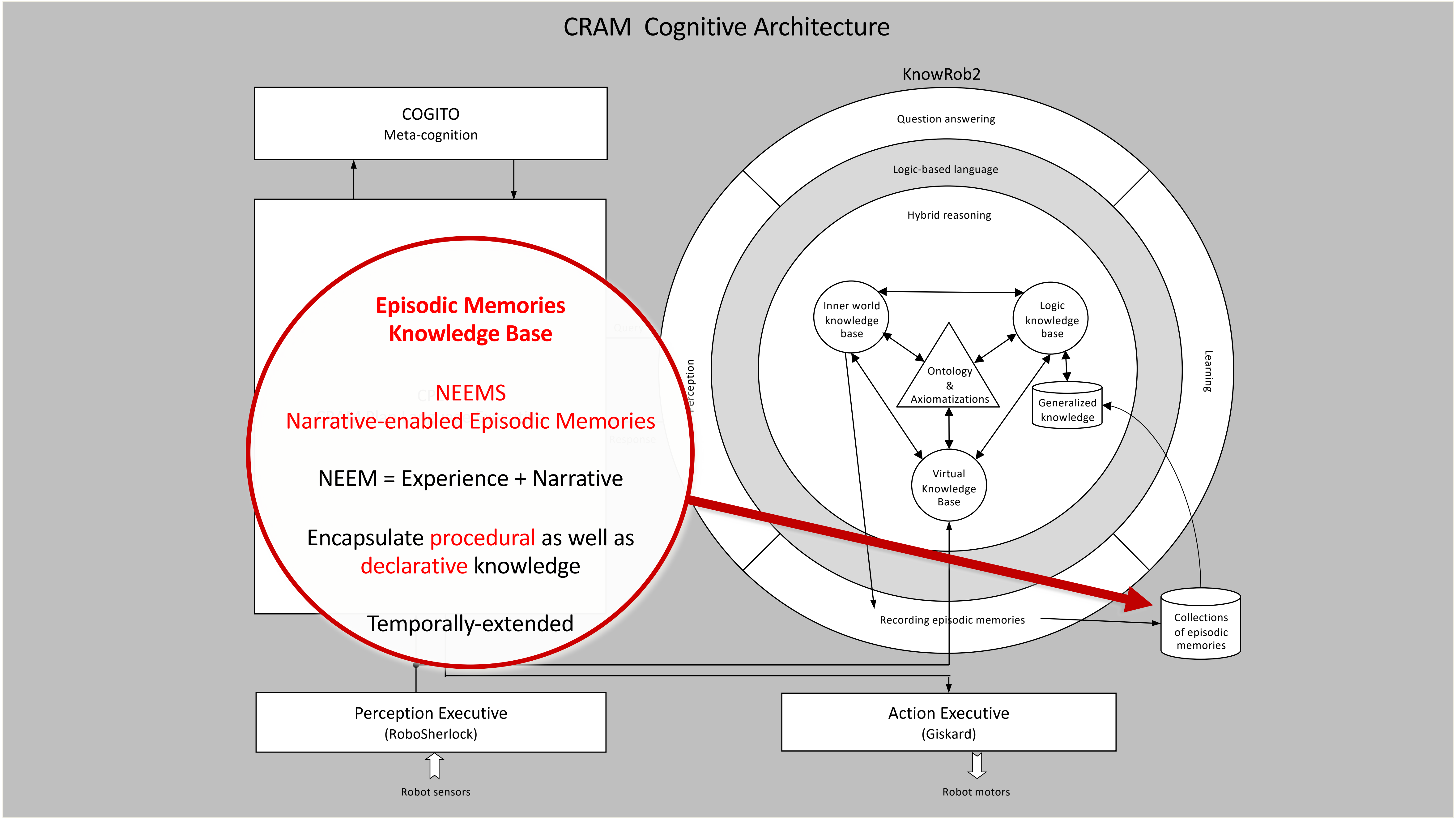
CRAM Cognitive Architecture



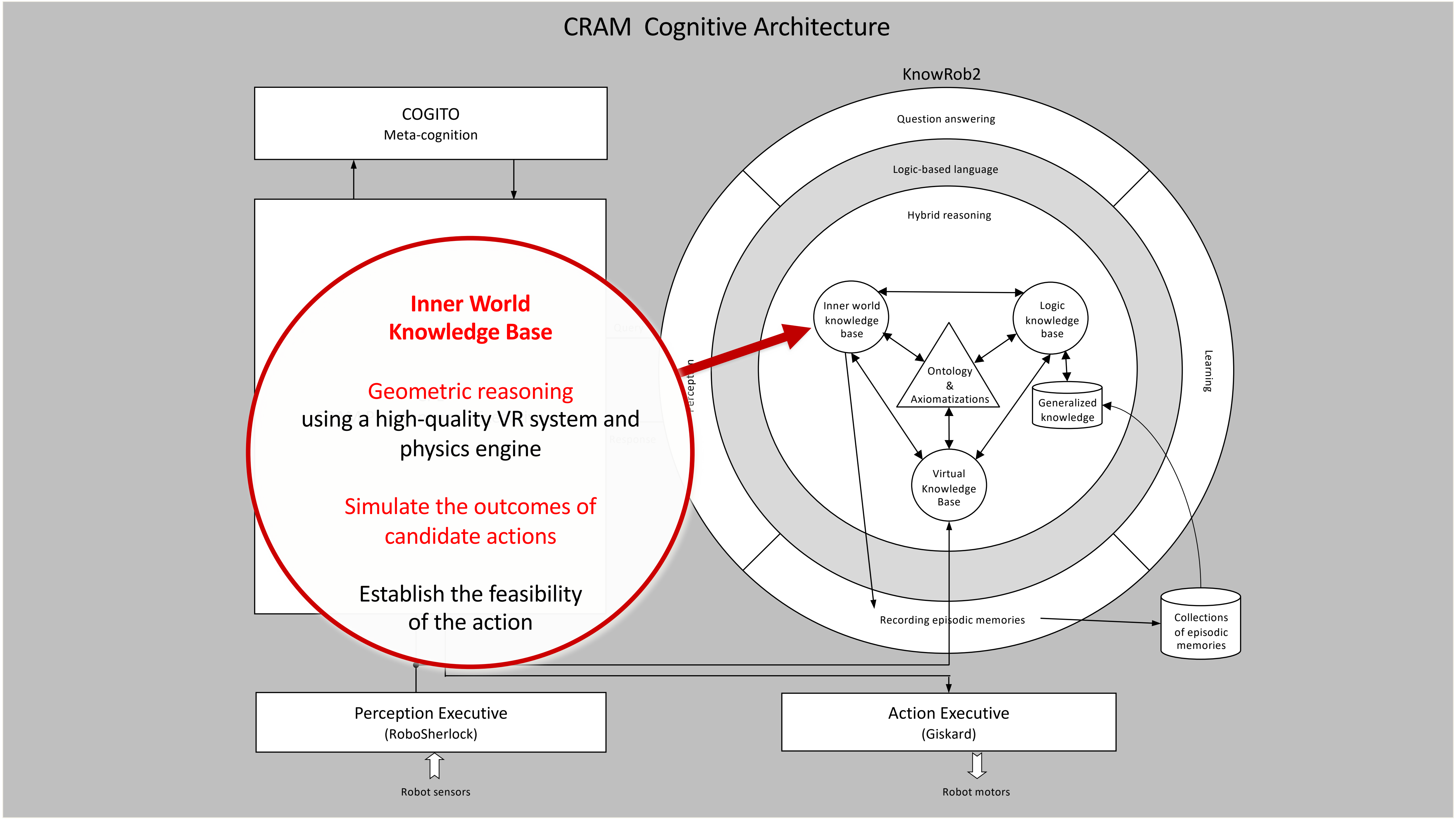


CRAM Cognitive Architecture
COGITO
Meta-cognition
CPL
CRAM Plan Language Executive
Query
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Learning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
ding episodic memories
Collections of episodic memories
Perception Executi
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors
CLP
Plan execution:
resolve the designators
by querying
a priori knowledge in the plan
KnowRob knowledge base
Perception Executive

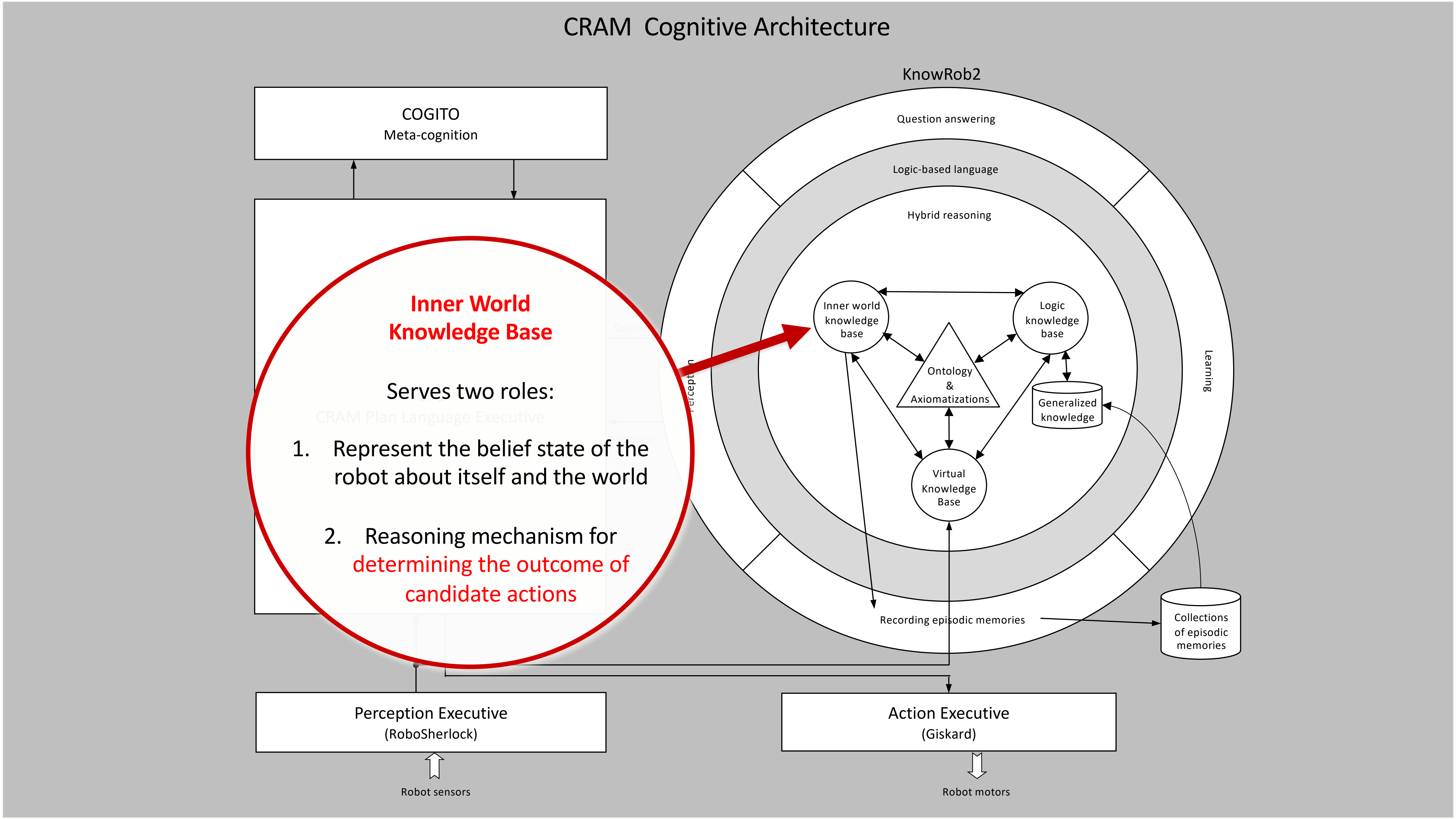

CRAM Cognitive Architecture
COGITO
Meta-cognition
Episodic Memories
Knowledge Base
Recording of robot's experiences:
(percepts, poses, control signals, ...
as it performed an activity)
+
Symbolic narrative description
(actions, motions, effects on robot,
effects on environment,
purpose, goal, context)
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Learning
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors

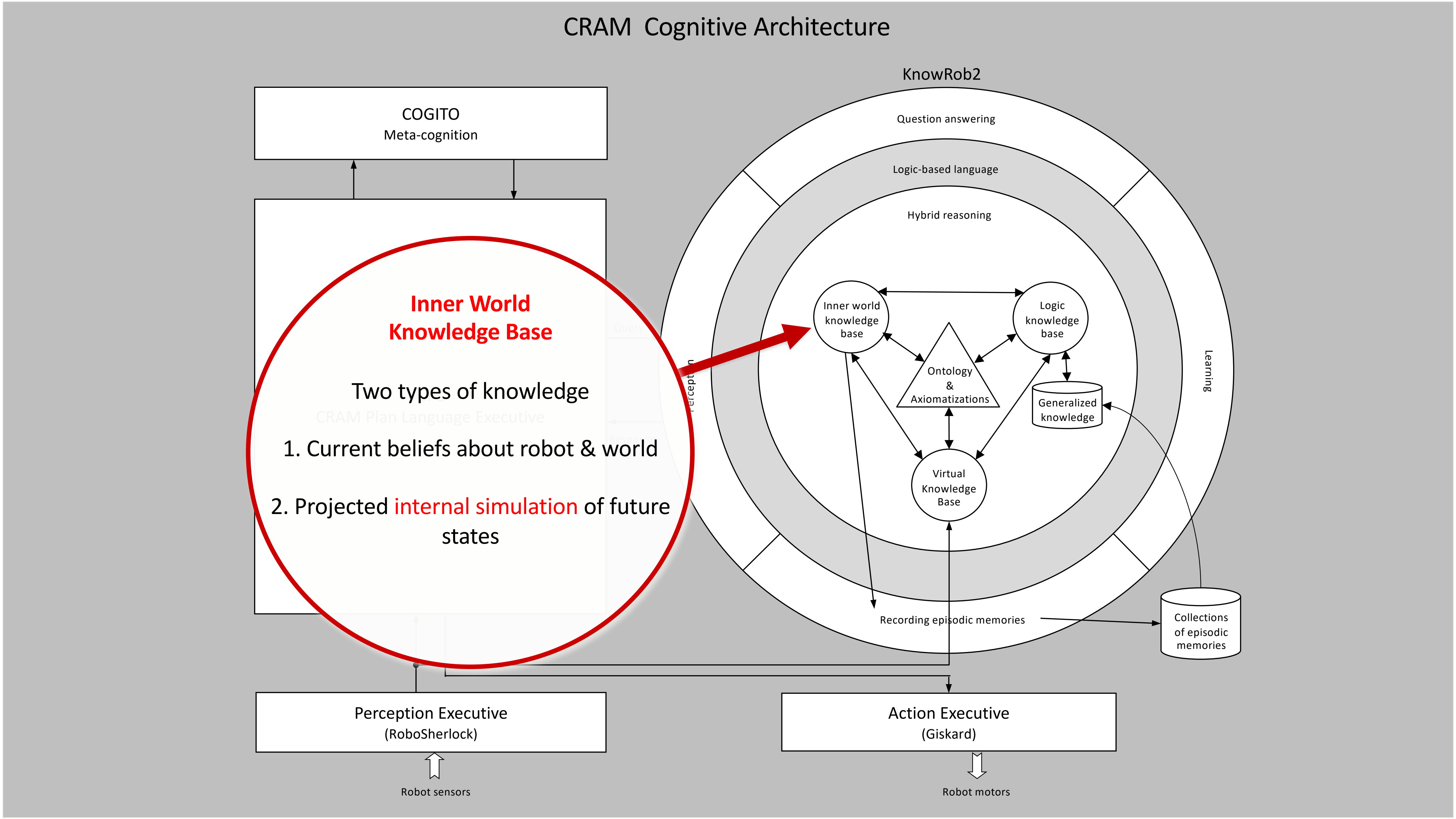


CRAM Cognitive Architecture
COGITO
Meta-cognition
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Learning
Recording episodic memories
Collections of episodic memories
Episodic Memories Knowledge Base
NEEMS
Narrative-enabled Episodic Memories
NEEM = Experience + Narrative
Encapsulate procedural as well as declarative knowledge
Temporally-extended
Perception Executive
(RoboSherlock)
Robot sensors
Action Executive
(Giskard)
Robot motors



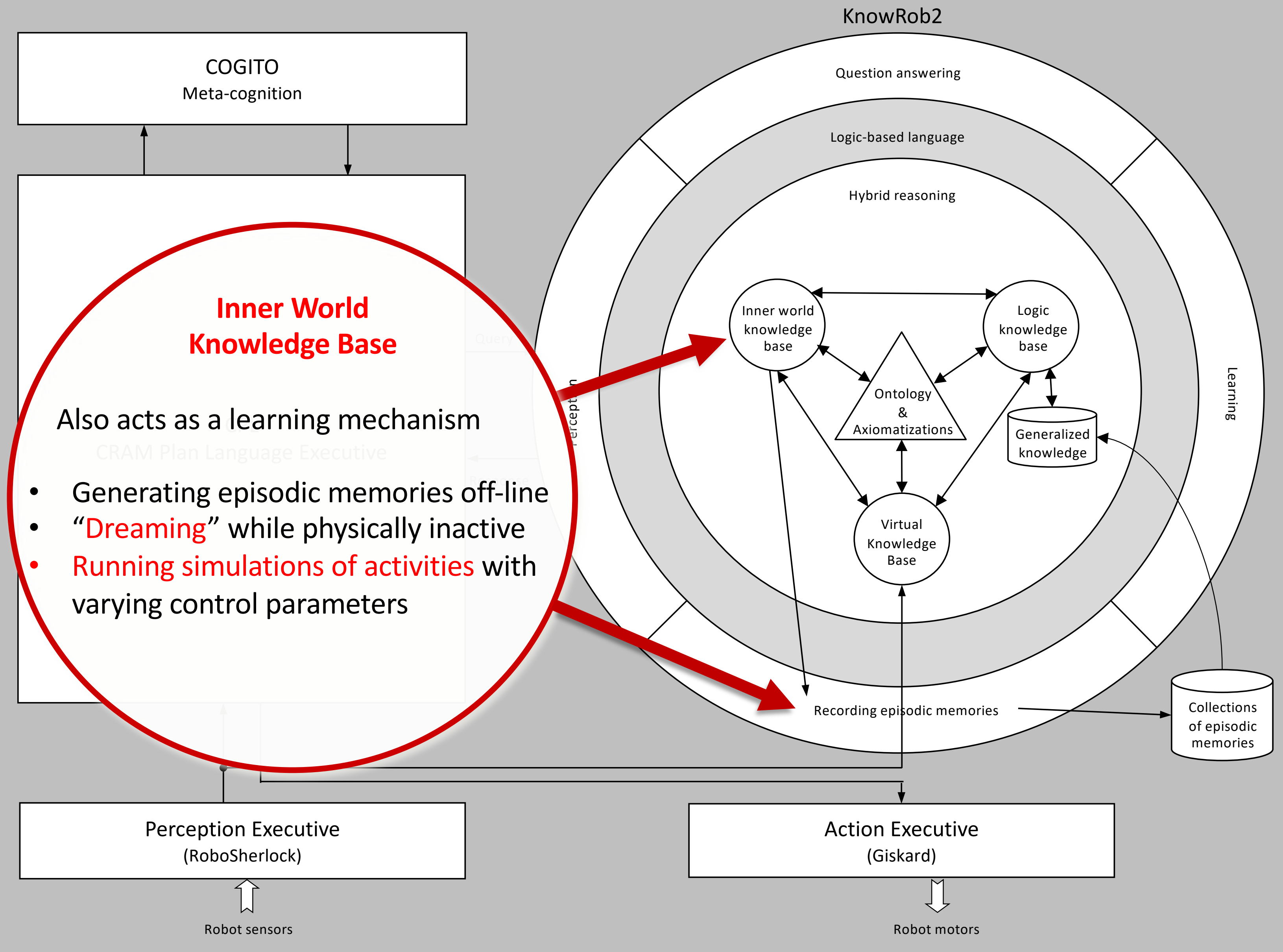
CRAM Cognitive Architecture
KnowRob2
COGITO
Meta-cognition
Inner World
Knowledge Base
Geometric reasoning
using a high-quality VR system and physics engine
Simulate the outcomes of candidate actions
Establish the feasibility of the action
Question answering
Logic-based language
Hybrid reasoning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Learning
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors

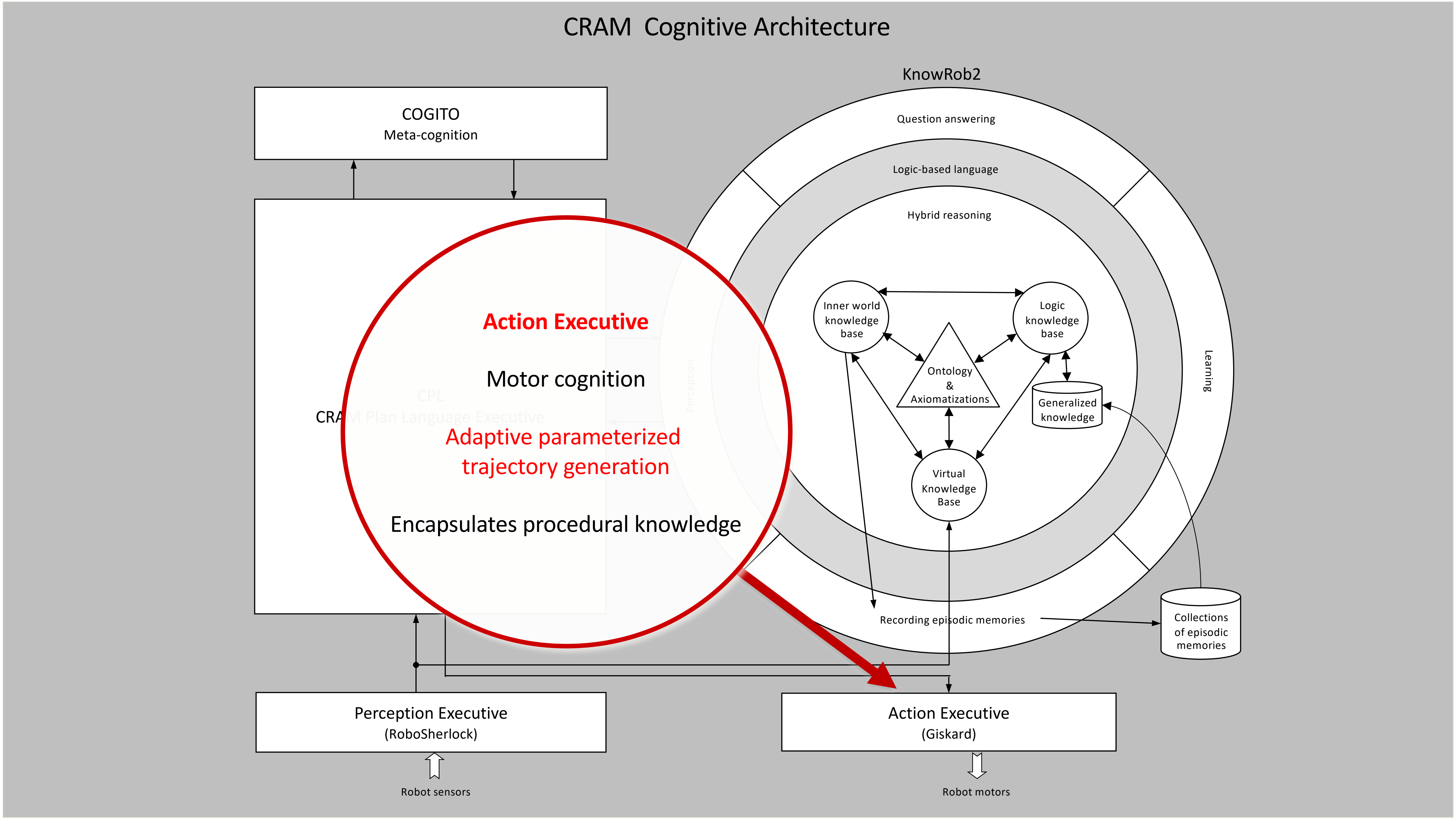

CRAM Cognitive Architecture
COGITO
Meta-cognition
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Learning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Recording episodic memories
Collections of episodic memories
Inner World Knowledge Base
Serves two roles:
1. Represent the belief state of the robot about itself and the world
2. Reasoning mechanism for determining the outcome of candidate actions
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors



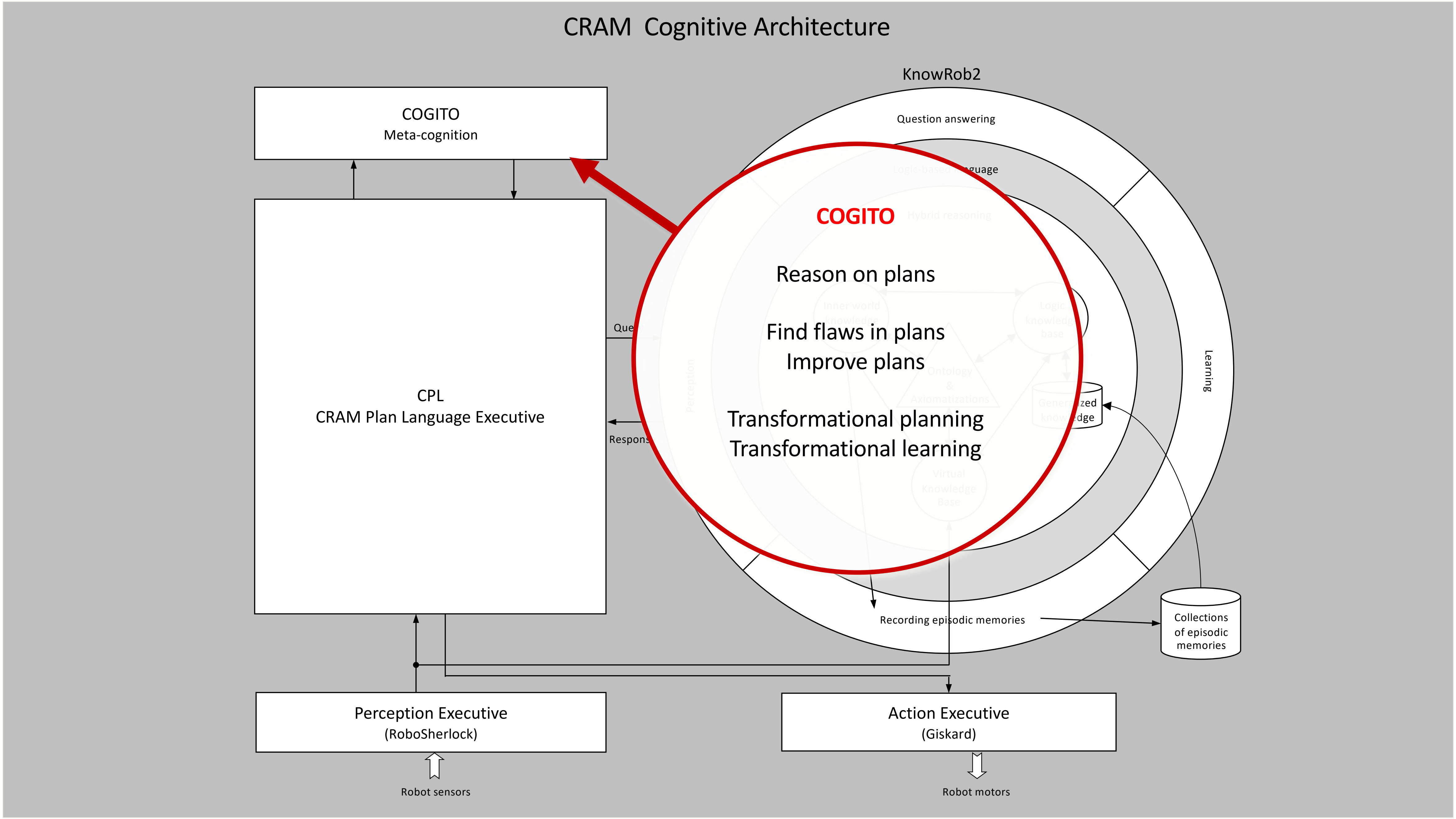
CRAM Cognitive Architecture
COGITO
Meta-cognition
Inner World
Knowledge Base
Two types of knowledge
1. Current beliefs about robot & world
2. Projected internal simulation of future states
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Learning
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Robot sensors
Action Executive
(Giskard)
Robot motors

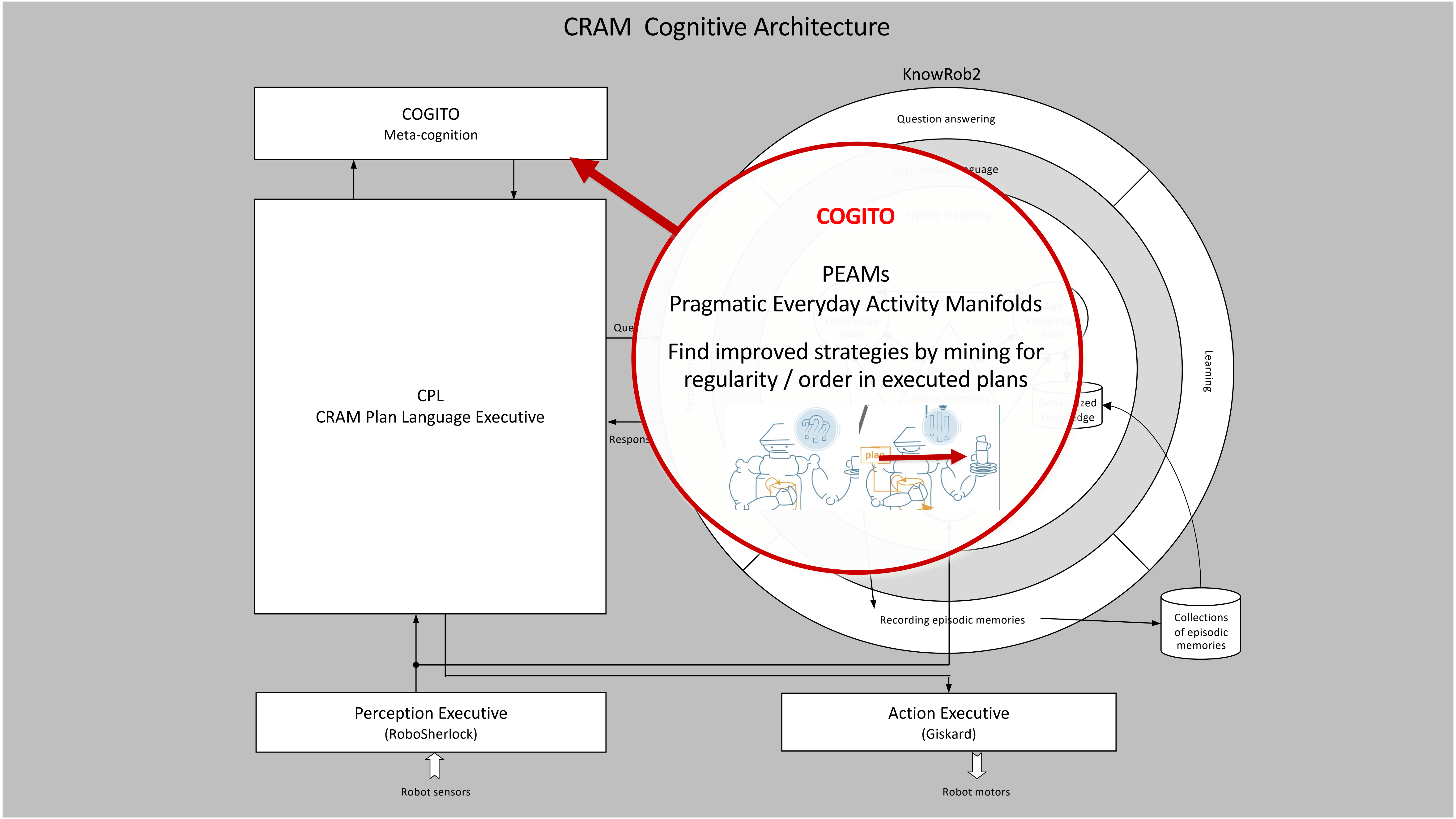
CRAM Cognitive Architecture

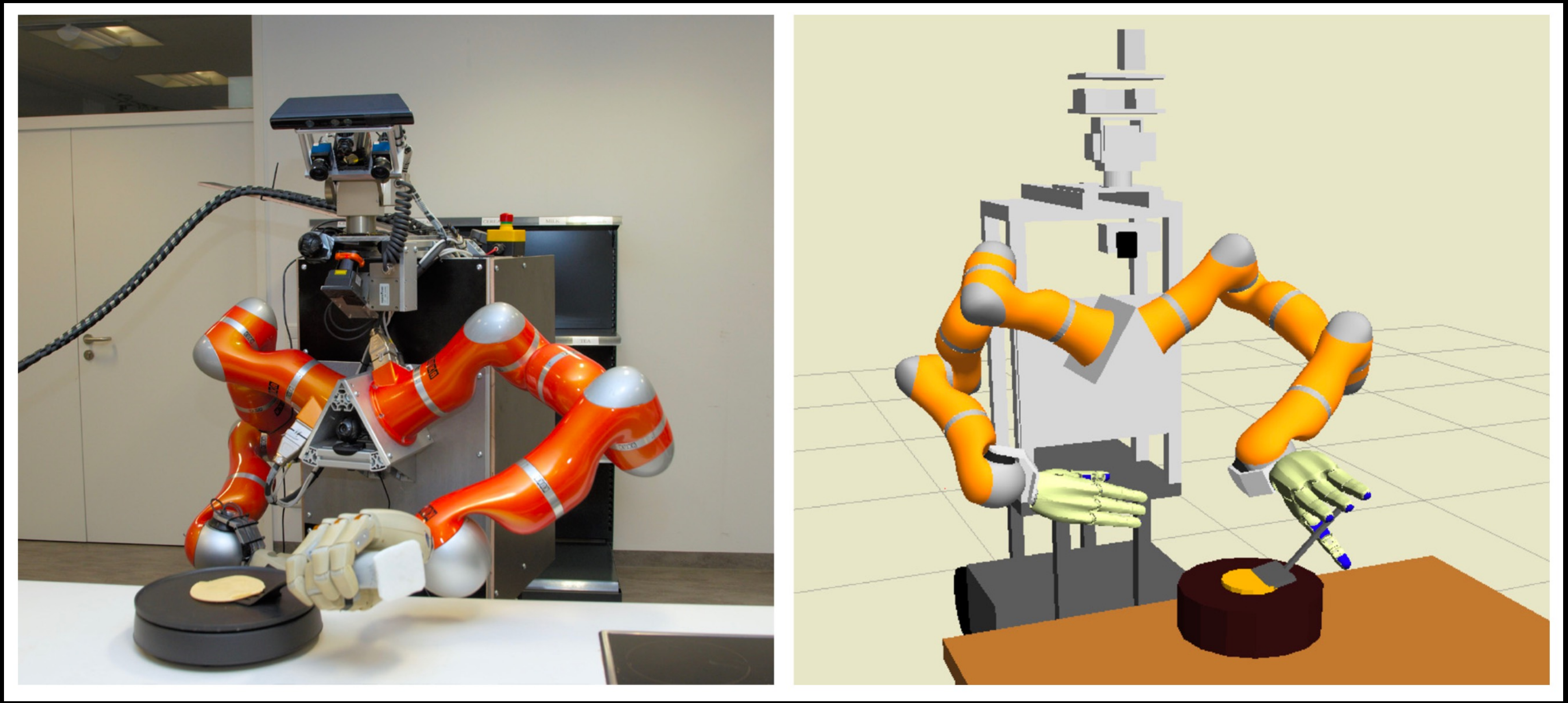




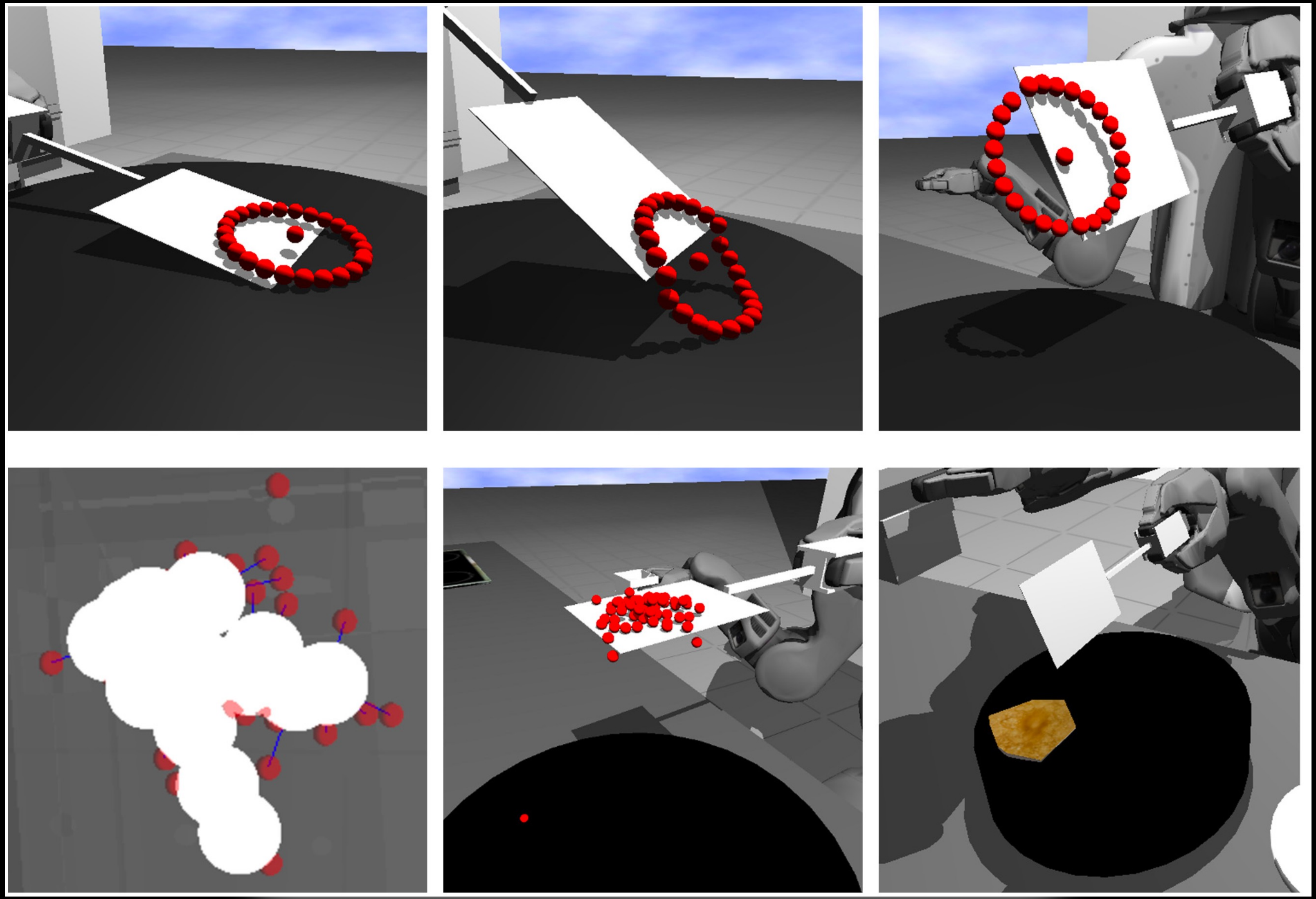
CRAM Cognitive Architecture
COGITO
Meta-cognition
CRAM Plan Language Executive
CPL
KnowRob2
Question answering
Logic-based language
Hybrid reasoning
Inner world knowledge base
Logic knowledge base
Ontology & Axiomatizations
Generalized knowledge
Virtual Knowledge Base
Learning
Perception
Recording episodic memories
Collections of episodic memories
Action Executive
Motor cognition
Adaptive parameterized trajectory generation
Encapsulates procedural knowledge
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors


CRAM Cognitive Architecture
KnowRob2
COGITO
Meta-cognition
Question answering
COGITO
Reason on plans
Find flaws in plans
Improve plans
Transformational planning
Transformational learning
CPL
CRAM Plan Language Executive
Learning
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors


CRAM Cognitive Architecture
KnowRob2
COGITO
Meta-cognition
Question answering
COGITO
PEAMs
Pragmatic Everyday Activity Manifolds
Find improved strategies by mining for regularity / order in executed plans
plan
Learning
CPL
CRAM Plan Language Executive
Recording episodic memories
Collections of episodic memories
Perception Executive
(RoboSherlock)
Action Executive
(Giskard)
Robot sensors
Robot motors



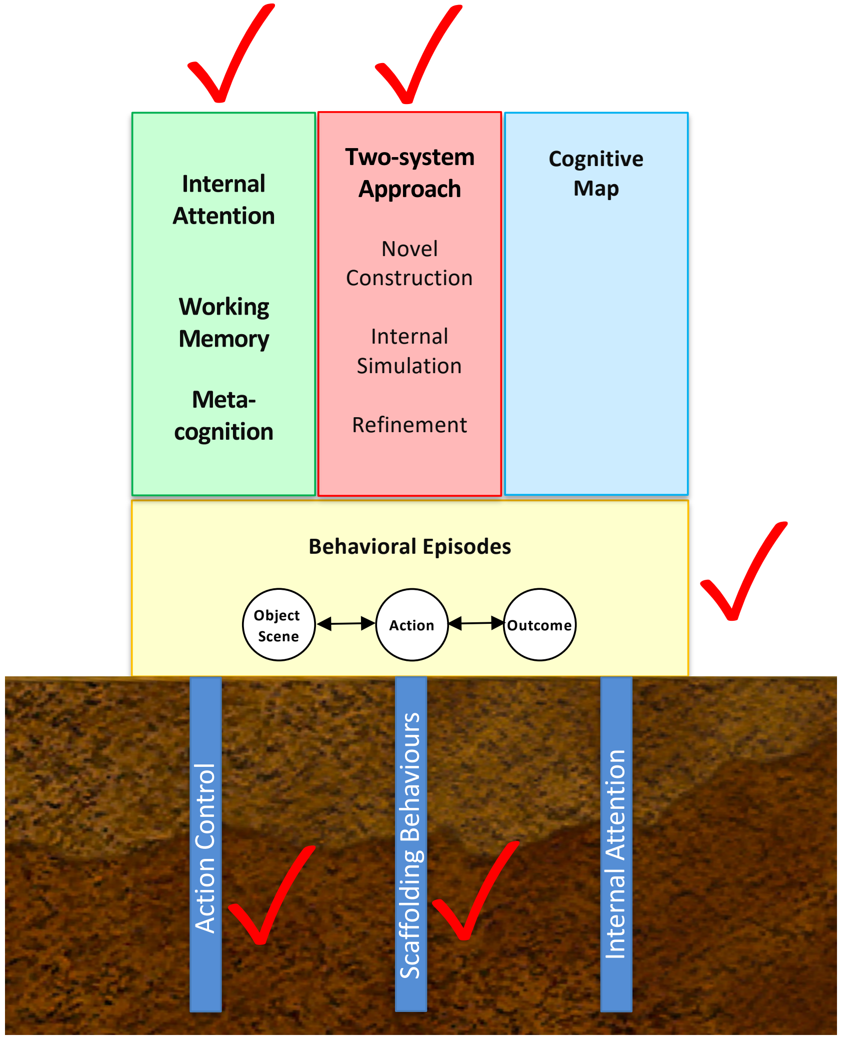
Internal Simulation
[Kunze and Beetz 2017]



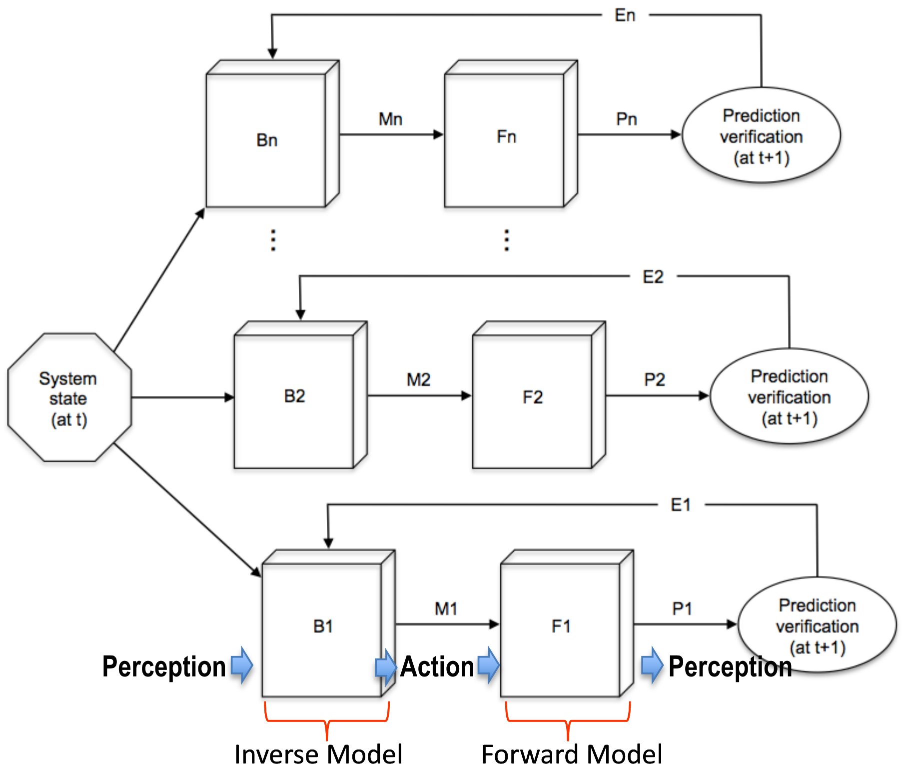
Internal Simulation

[Kunze and Beetz 2017]

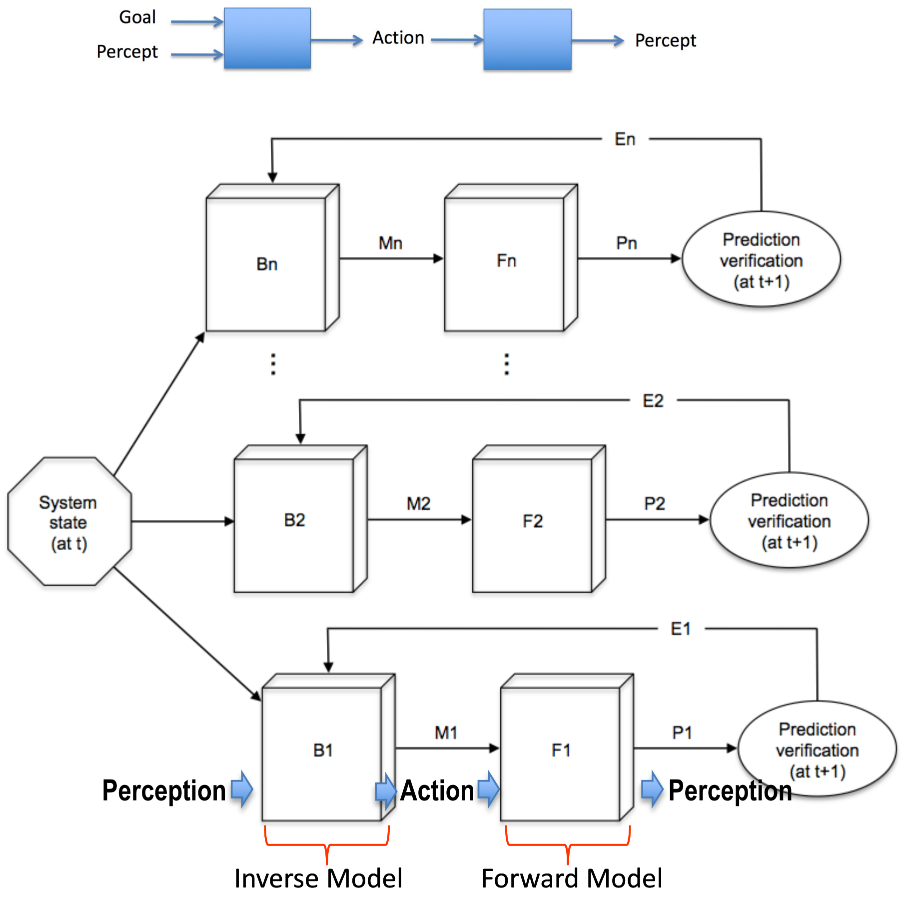
Situation Model Framework



HAMMER

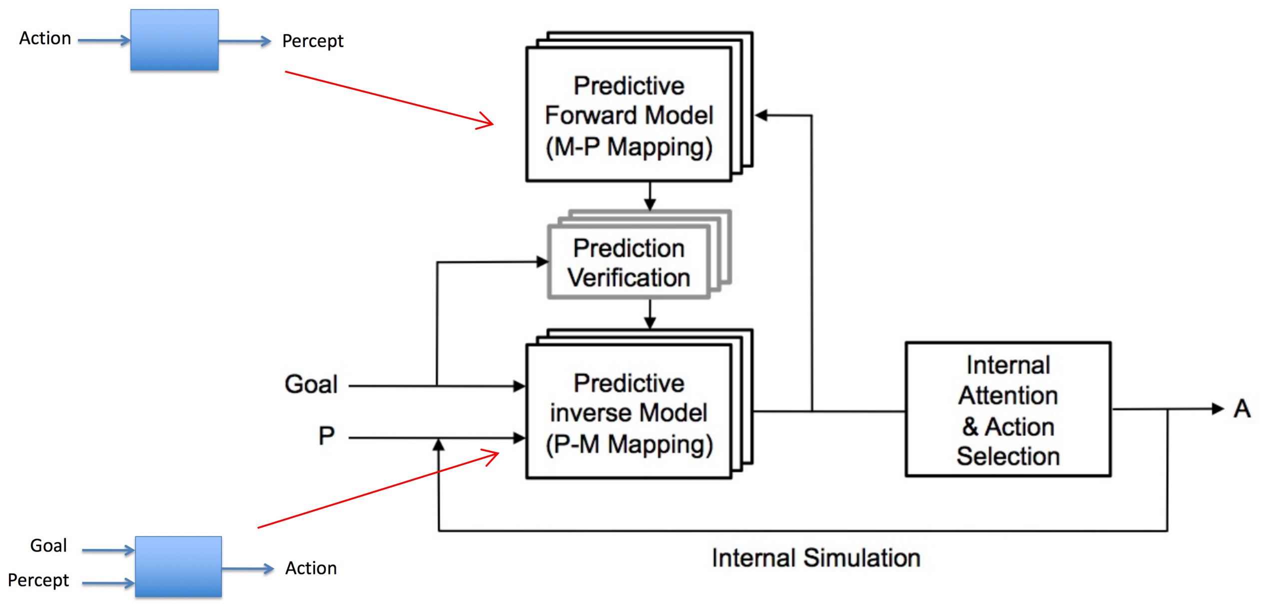


Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361– 369, 2006.



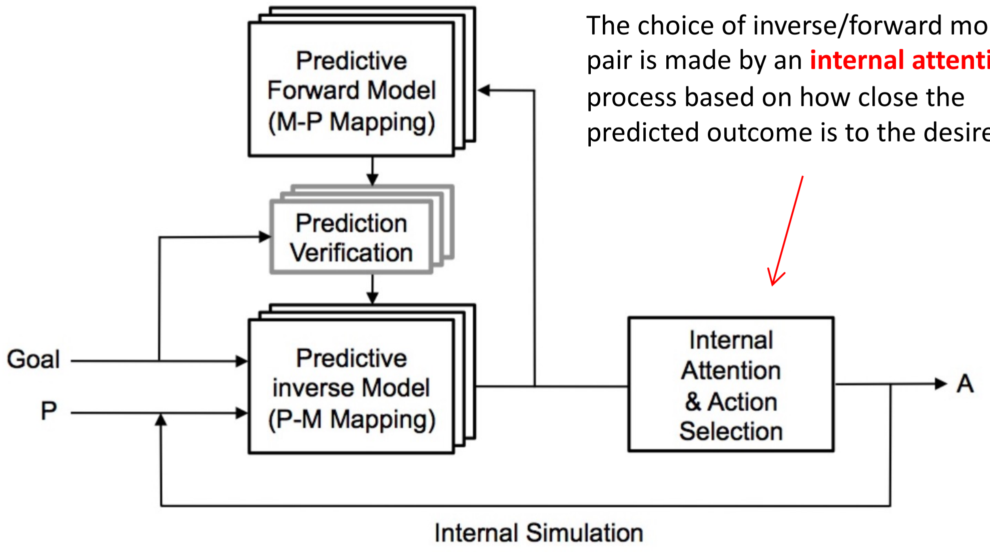
Goal
Percept
Action
Percept
En
Bn
Mn
Fn
Pn
Prediction verification (at t+1)
E2
System state (at t)
B2
M2
F2
P2
Prediction verification (at t+1)
E1
B1
M1
F1
P1
Prediction verification (at t+1)
Perception
Action
Perception
Inverse Model
Forward Model

HAMMER



Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361– 369, 2006.

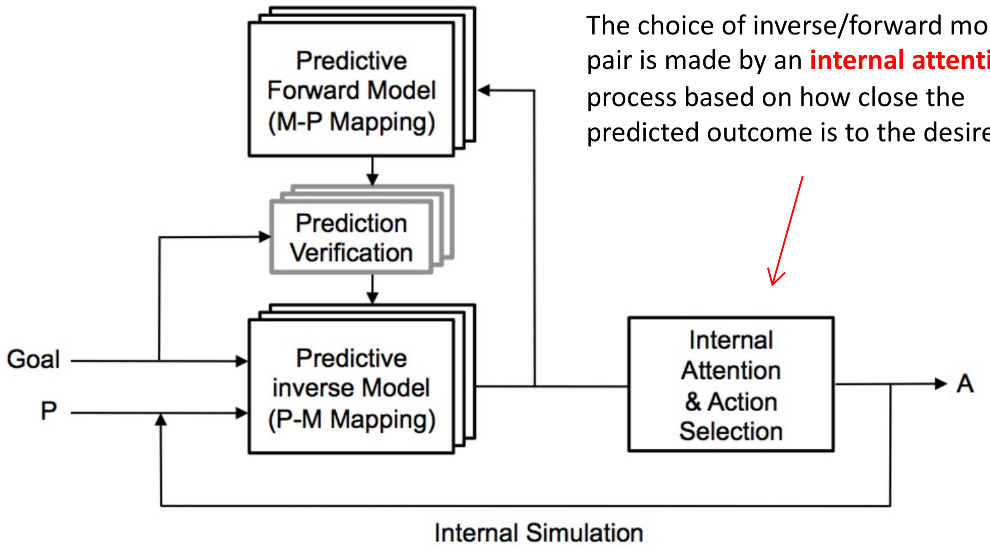
HAMMER



The choice of inverse/forward model pair is made by an **internal attention** process based on how close the predicted outcome is to the desired one

Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361– 369, 2006.

HAMMER

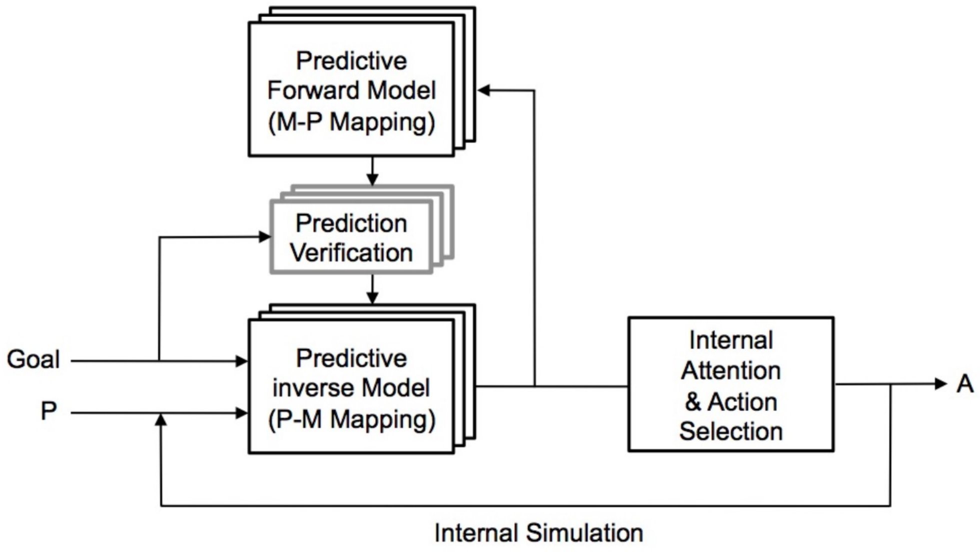


The choice of inverse/forward model pair is made by an **internal attention** process based on how close the predicted outcome is to the desired one

Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361– 369, 2006.

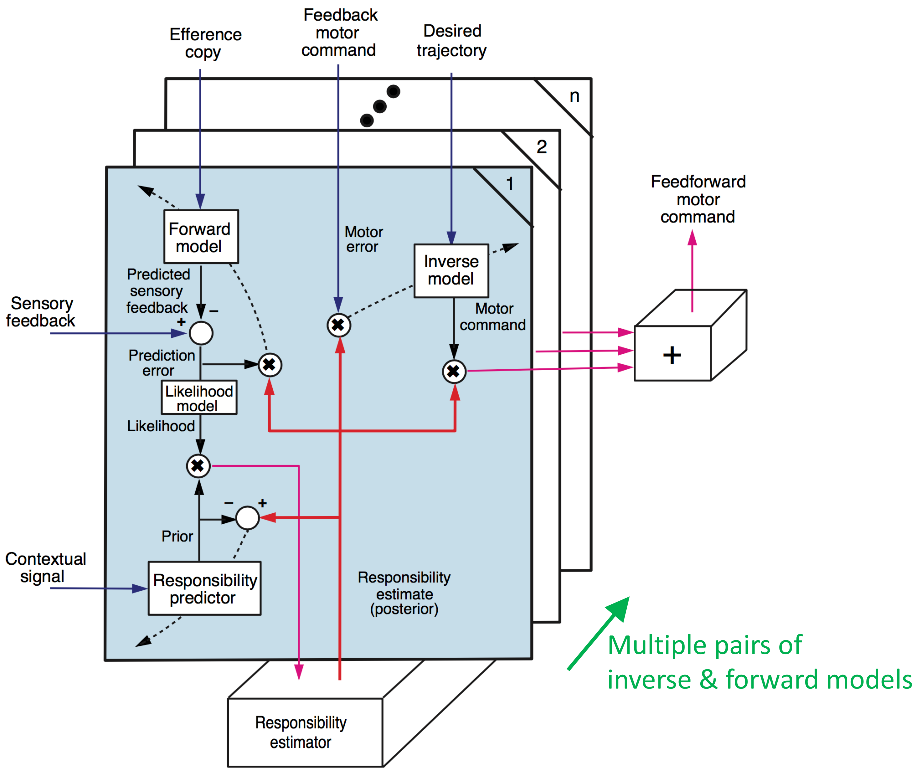
HAMMER

Provides for hierarchical composition of primitive actions
into more complex sequences



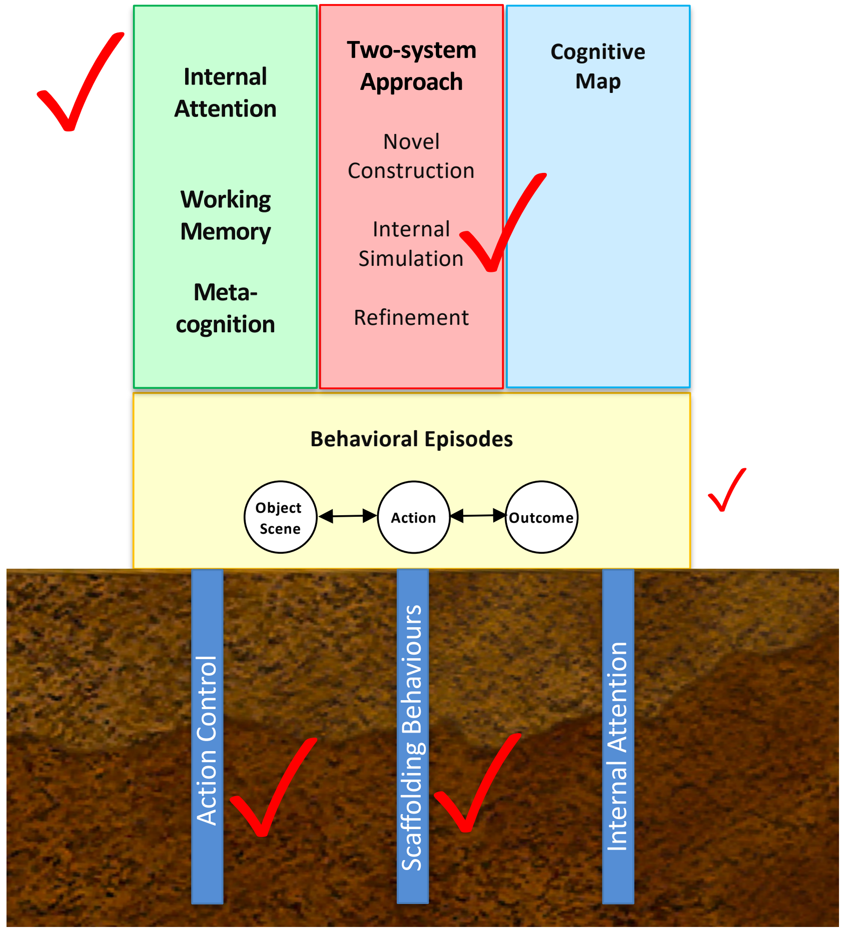
Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361– 369, 2006.

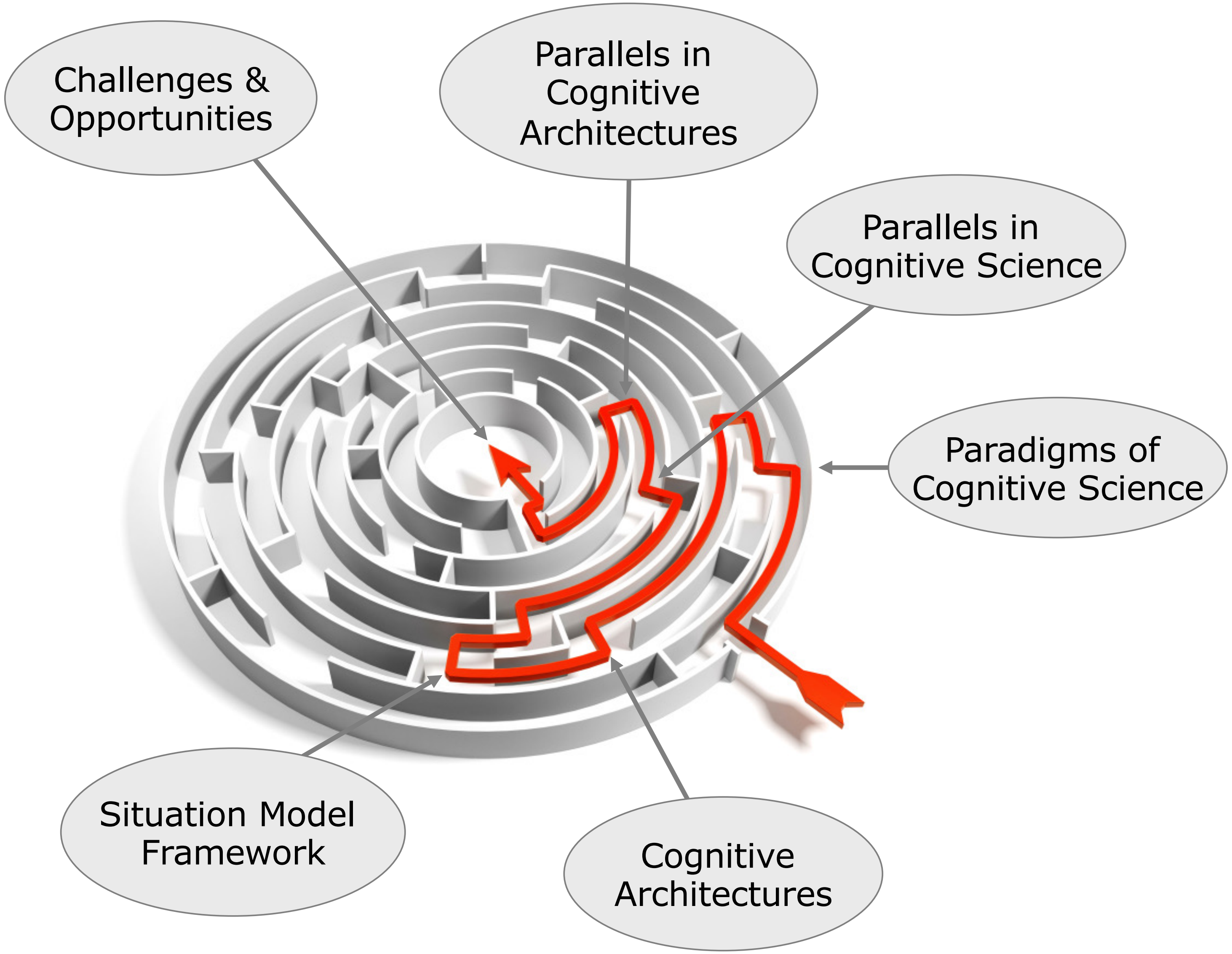
Internal Simulation

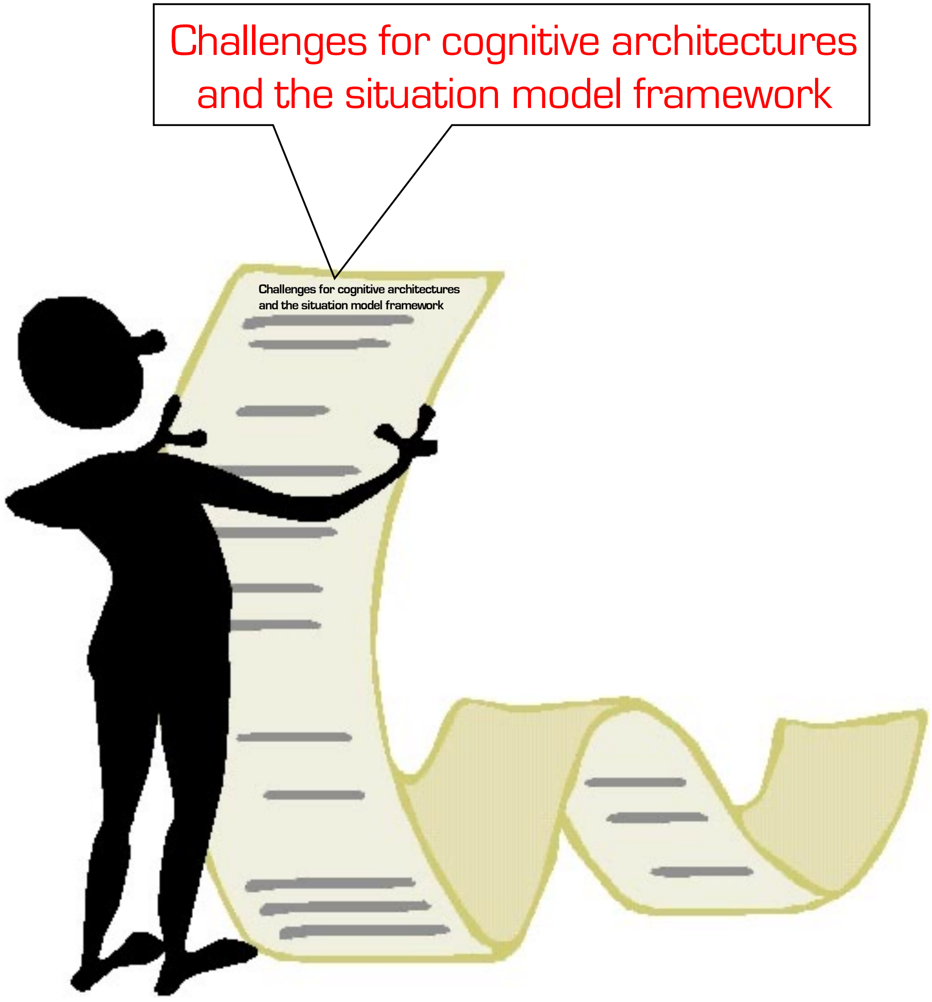


D. Wolpert, R. C. Miall, and M. Kawato. Internal models in the cerebellum. Trends in Cognitive Sciences, 2(9):338–347, 1998.

Situation Model Framework




Challenges &
Opportunities
Parallels in
Cognitive
Architectures
Parallels in
Cognitive Science
Paradigms of
Cognitive Science
Situation Model
Framework
Cognitive
Architectures



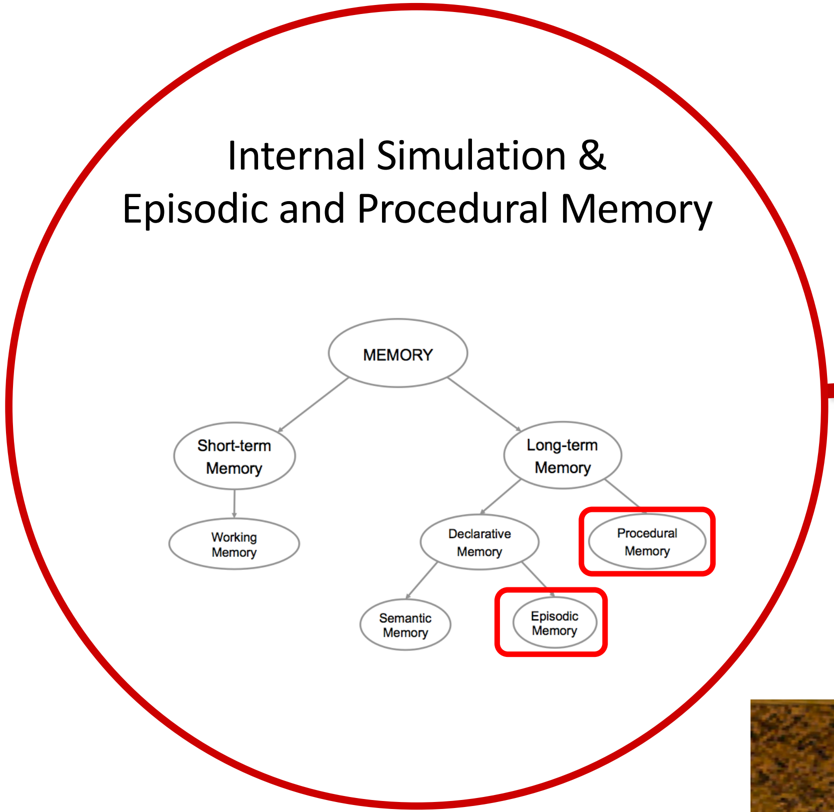
1. Decomposition, reconstruction, and recombination of behavioural episodes
2. Hierarchical behavioural episodes
3. Networks of behavioural episodes
4. Multiple levels of abstraction in internal simulation
5. Multiple timescales in internal simulation
6. Situation models vs. cognitive maps
7. Context sensitivity: what criteria are used for attention?
8. Autonomy: extrinsic vs. intrinsic goals

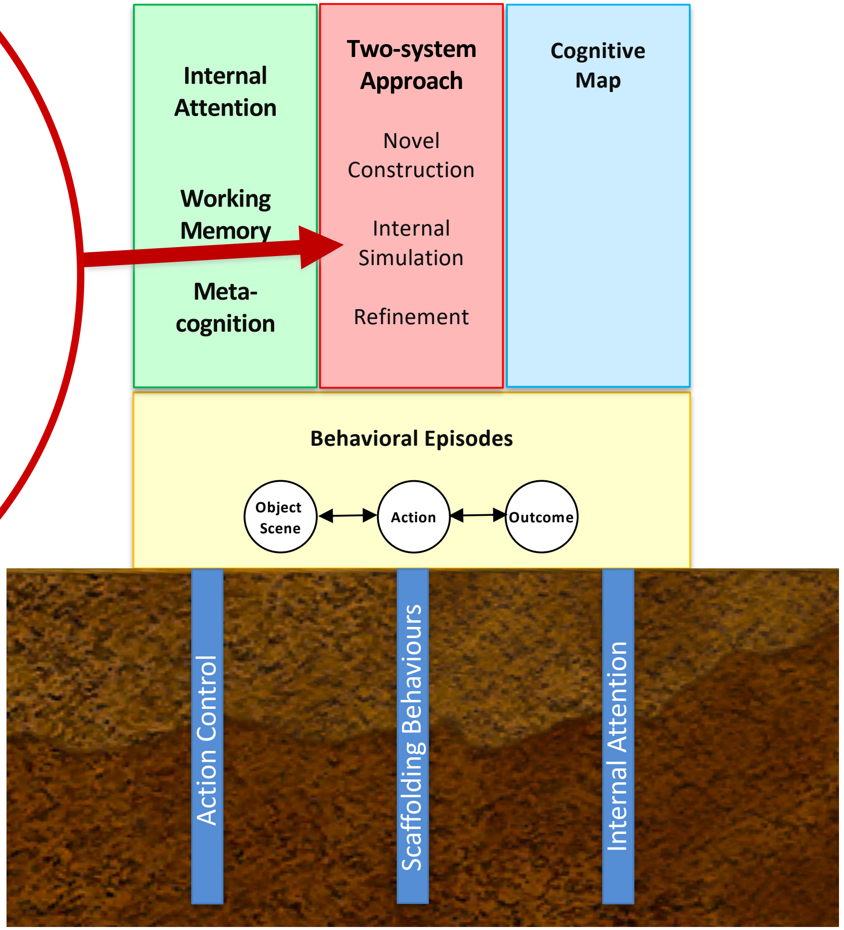
Opportunities

Episodic memory and episodic future thinking can be modulated by semantic memory

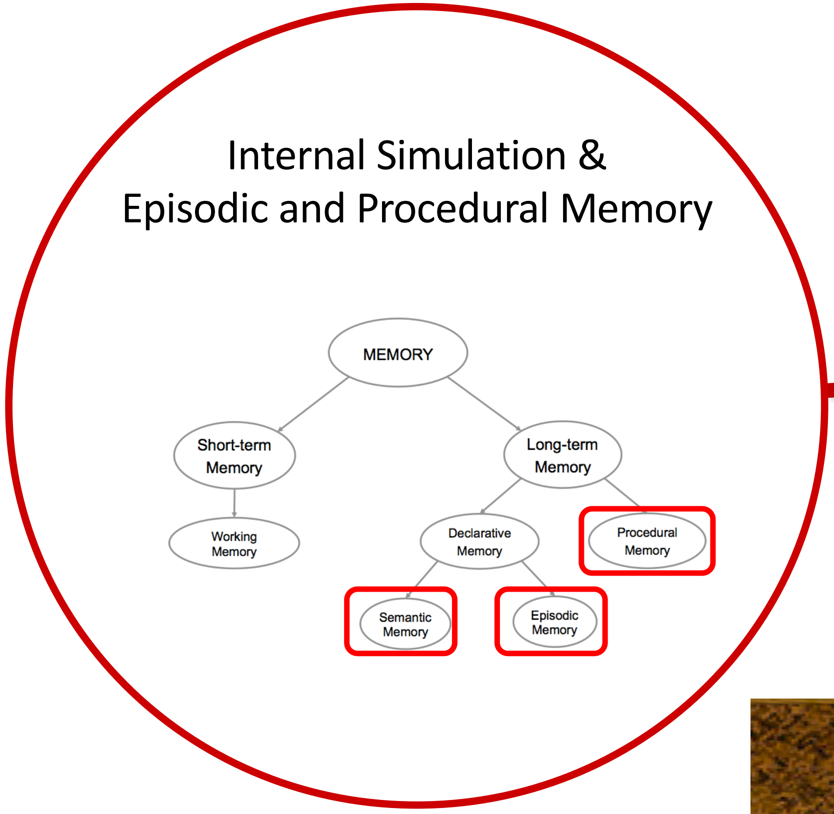
D. L. Schacter, D. R. Addis, D. Hassabis, V. C. Martin, R. N. Spreng, and K. K. Szpunar, “The future of memory: Remembering, imagining, and the brain,” Neuron, vol. 76, pp. 677–694, 2012.

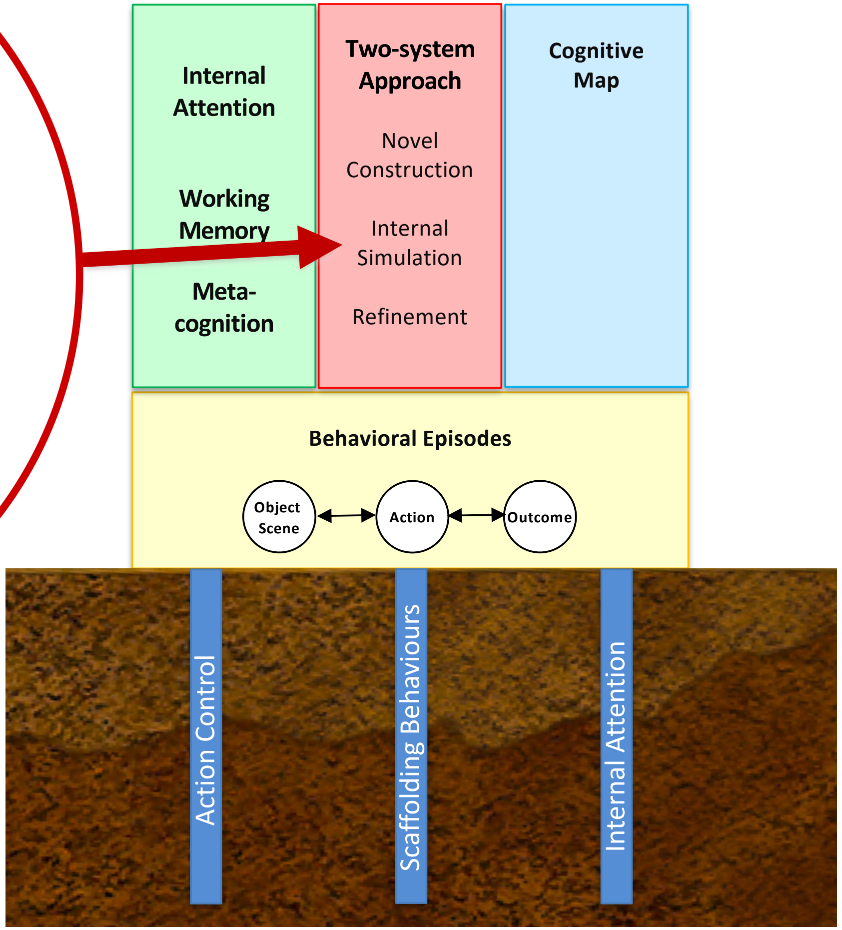
Situation Model Framework





Situation Model Framework





Please note our announcement concerning Coronavirus / Covid 19.

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

About Dagstuhl | Program | Publications | Library | dblp

You are here: **Program** » **Seminar Calendar** » Seminar Homepage

Seminar Calendar
- All Events
- Dagstuhl Seminars
- Dagstuhl Perspectives
- GI-Dagstuhl Seminars
- Summer Schools
- Events
- Research Guests
- Expenses
- Planning you visit / check-in

https://www.dagstuhl.de/19021

January 6 – 11 , 2019, Dagstuhl Seminar 19021

Joint Processing of Language and Visual Data for Better Automated Understanding

Organizers

Yun Fu (Northeastern University – Boston, US)
Marie-Francine Moens (KU Leuven, BE)
Lucia Specia (Imperial College London, GB)
Tinne Tuytelaars (KU Leuven, BE)

Documentation

In the series Dagstuhl Reports each Dagstuhl Seminar and Dagstuhl Perspectives Workshop is documented. The seminar organizers, in cooperation with the collector, prepare a report that includes contributions from the participants' talks together with a summary of the seminar.

Download overview leaflet (PDF).

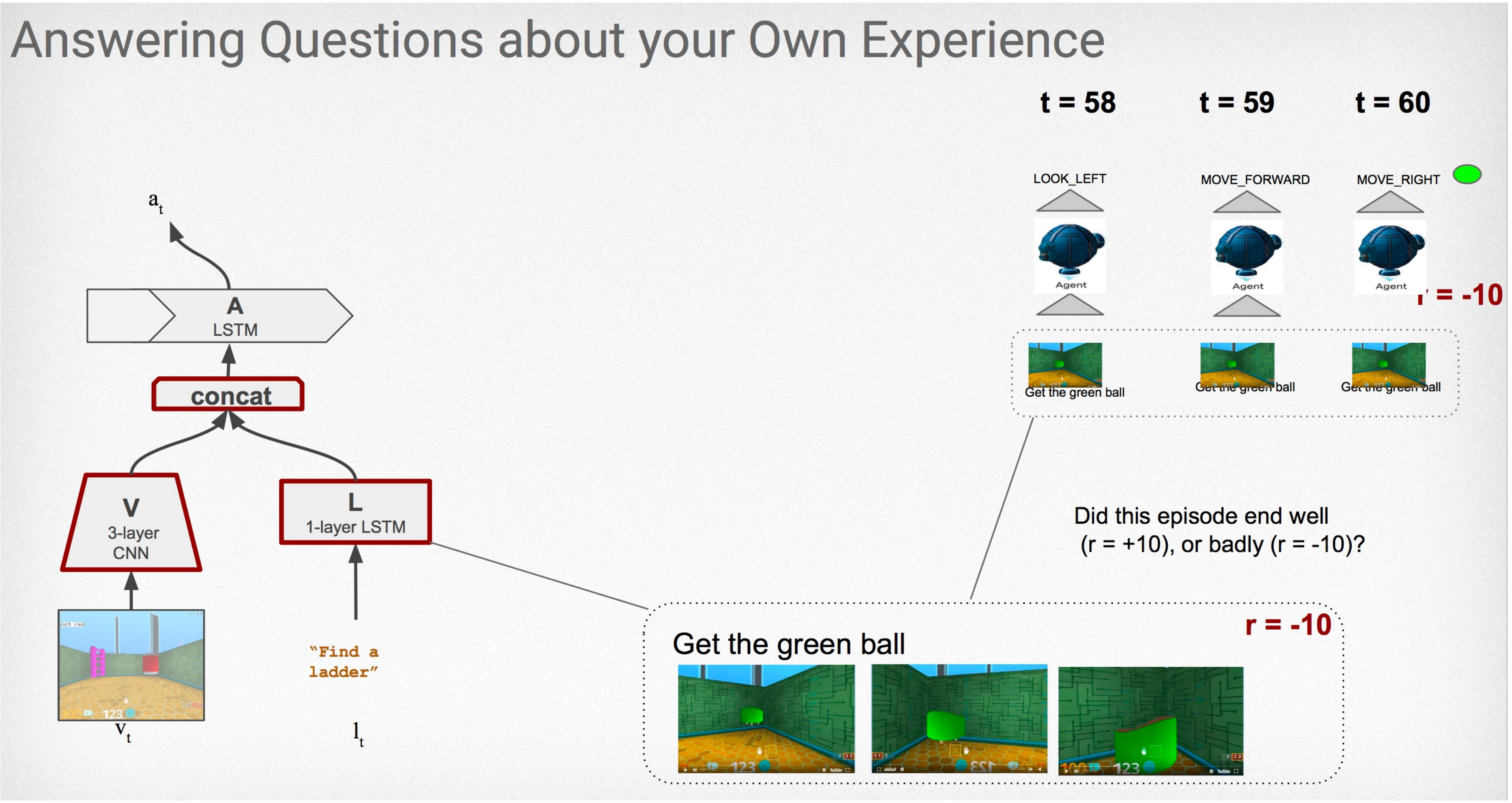
Publications

Furthermore, a comprehensive peer-reviewed collection of research papers can be published in the series Dagstuhl Follow-Ups.

Dagstuhl's Impact

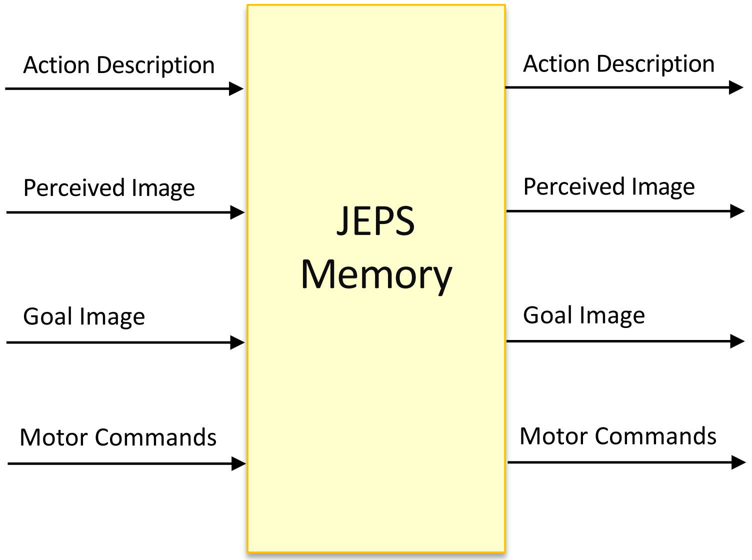
Please inform us when a publication was published as a result from your seminar. These publications are listed in the category Dagstuhl's Impact and are presented on a special shelf on the ground floor of the library.

https://www.dagstuhl.de/en/program/calendar/semhp/?semnr=19021

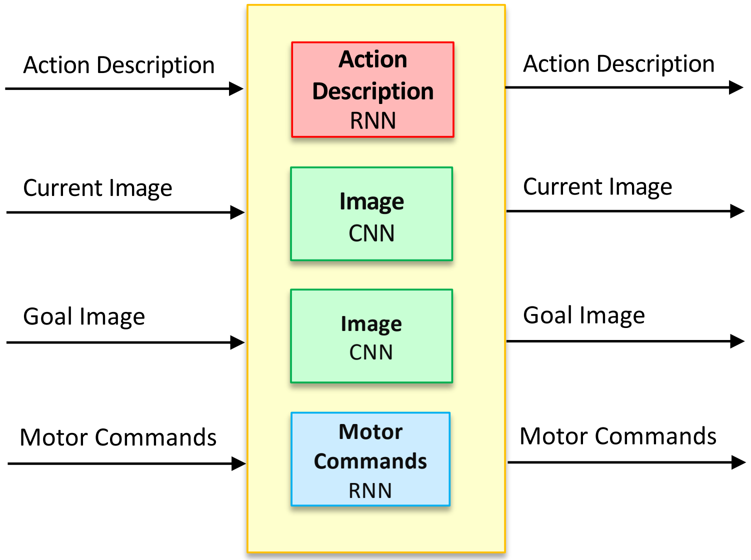


Stephen Clark, "Grounded Language Learning in Virtual Environments", Dagstuhl Seminar 19021: Joint Processing of Language and Visual Data for Better Automated Understanding, January 2019.

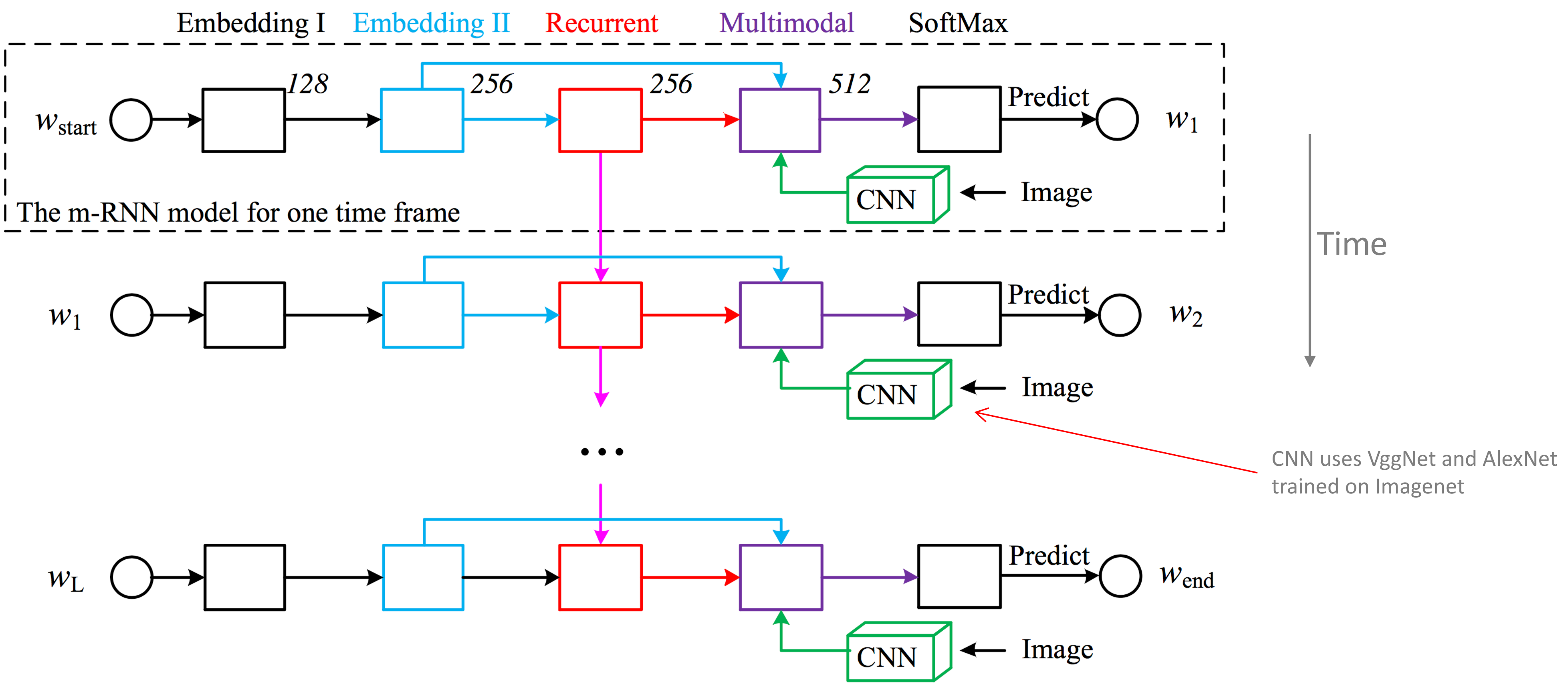
Multimodal Hetero-associative Memory



Multimodal Hetero-associative Memory

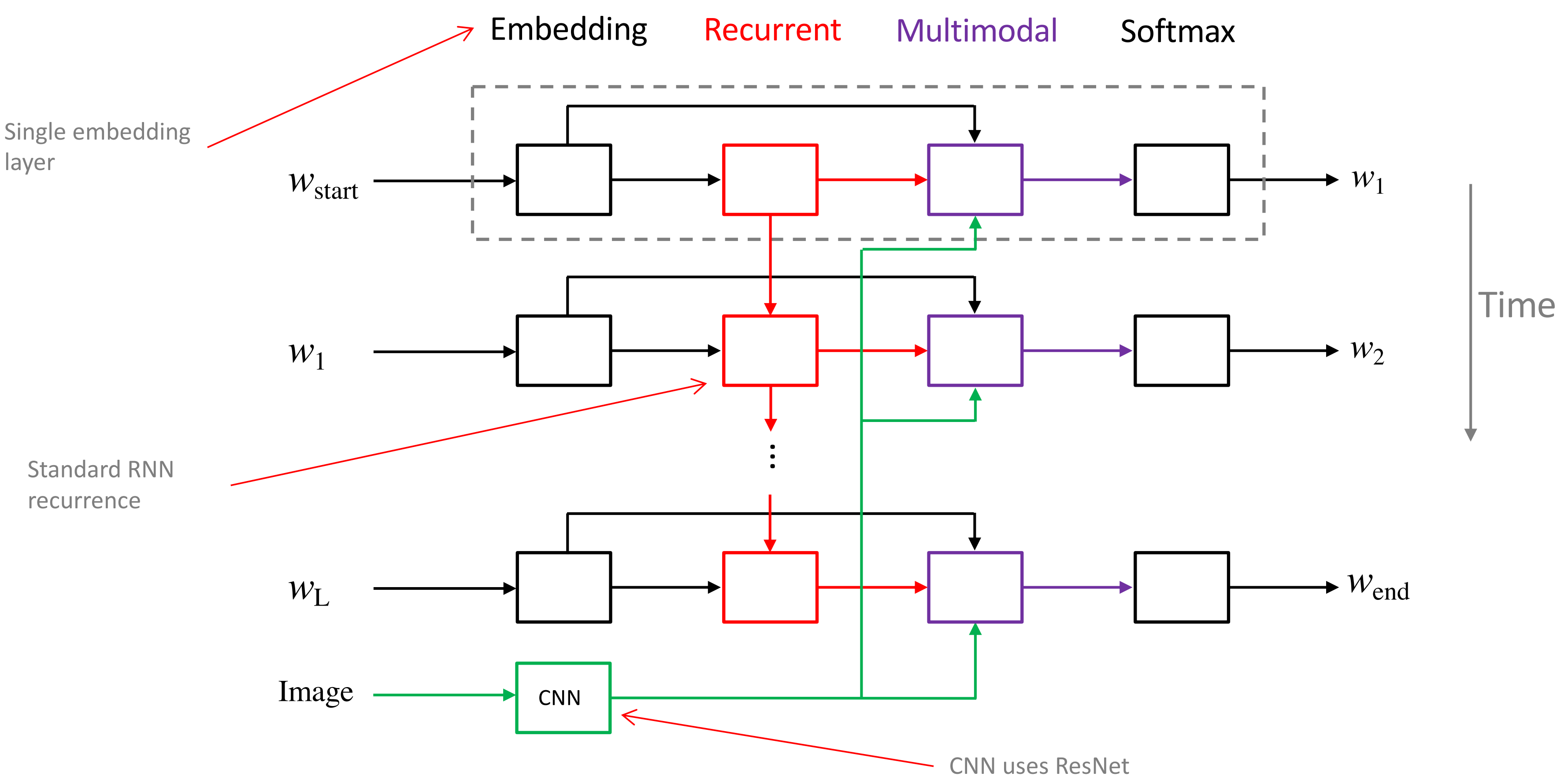


Deep Image Captioning and Image Recall



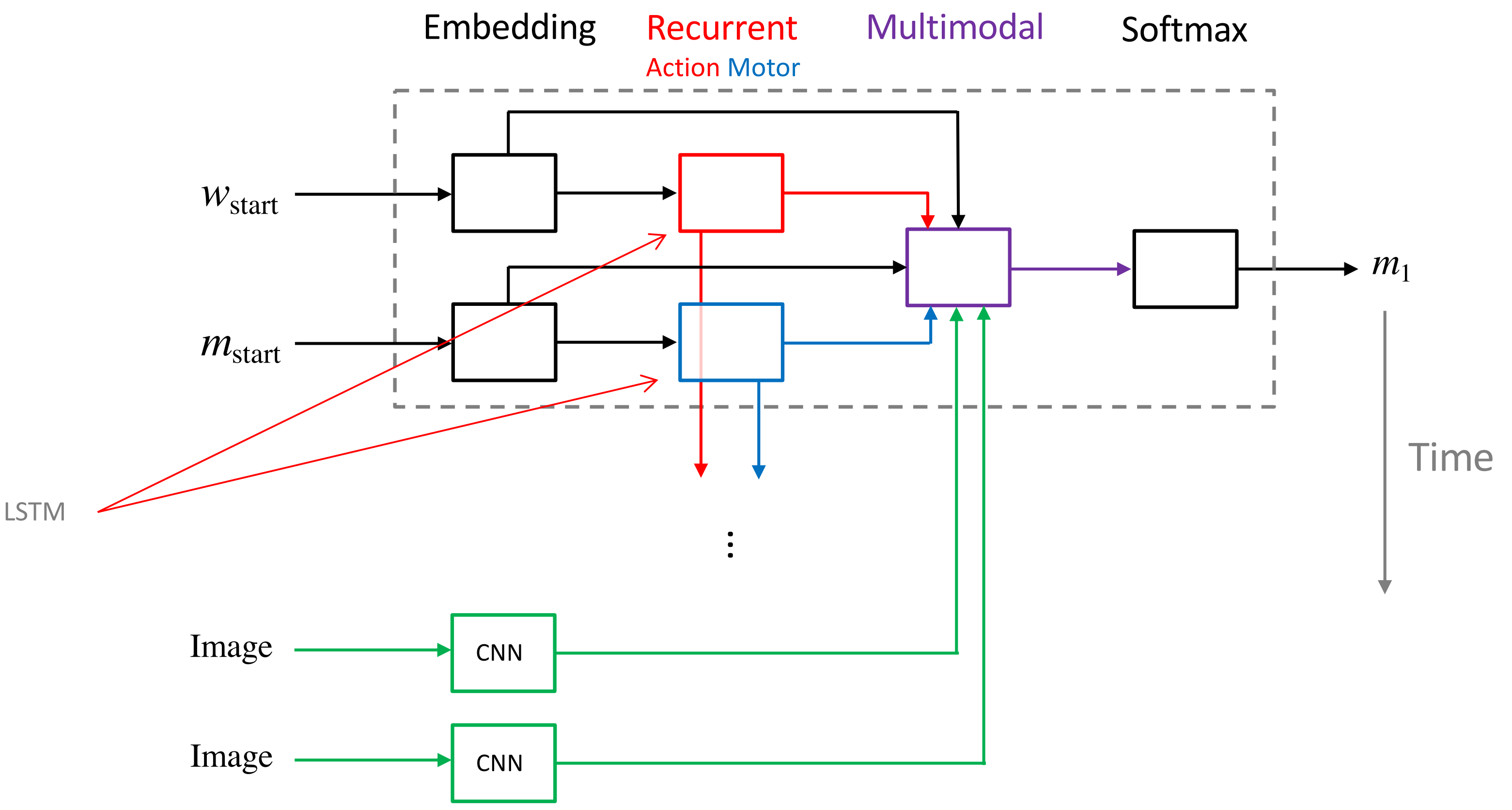
J. Mao, W. Xu, Y. Yang, Z. Huang, and A. Yuille. Deep Captioning with Multimodal Recurrent Neural Networks (M-RNN). ICLR 2015.

Alternative Architecture



A. K. Gebreselasie. Towards a Multimodal Hetero-associative Memory based on a deep image captioning model, Research Report, Carnegie Mellon University Africa, 2020.

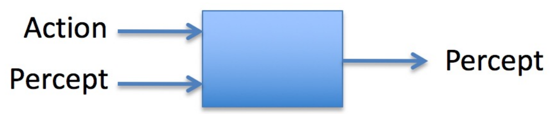
Multimodal Hetero-associative Memory

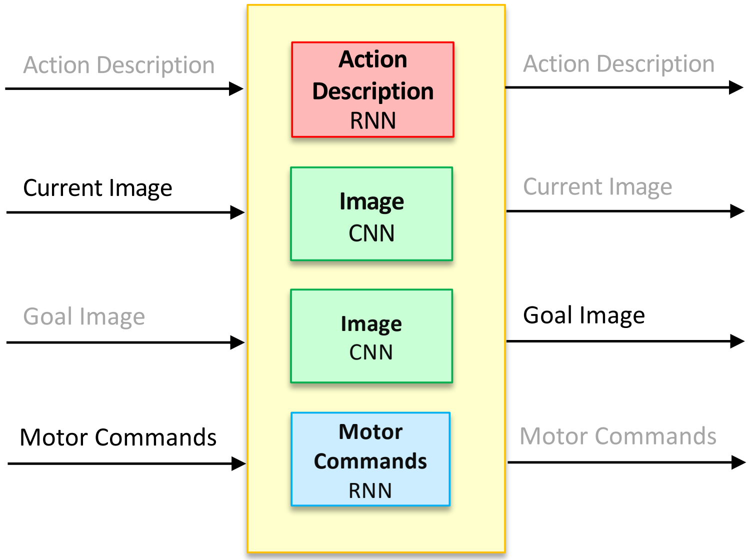


Time

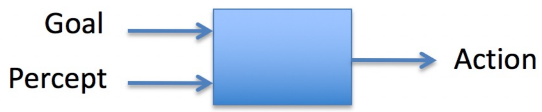
A. K. Gebreselasie. work in progress, Carnegie Mellon University Africa, 2020.

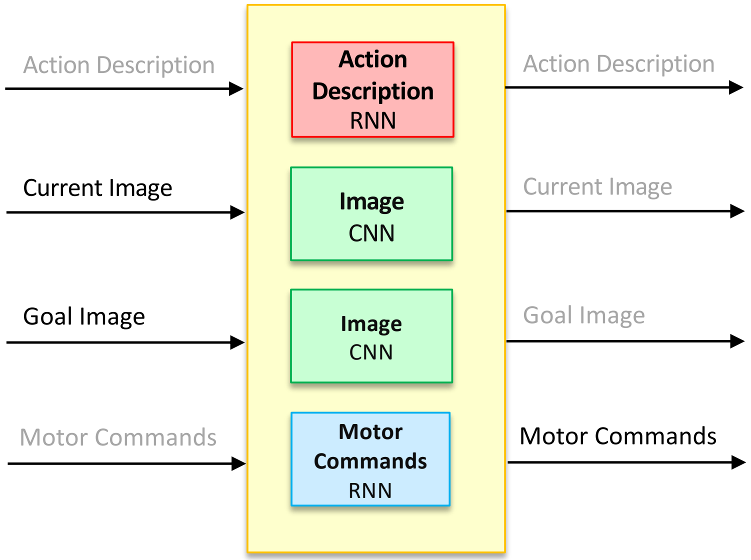
Forward Model



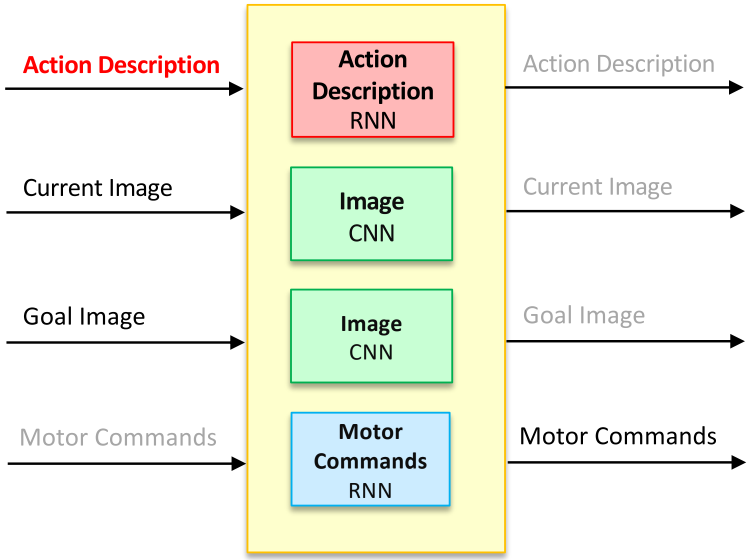


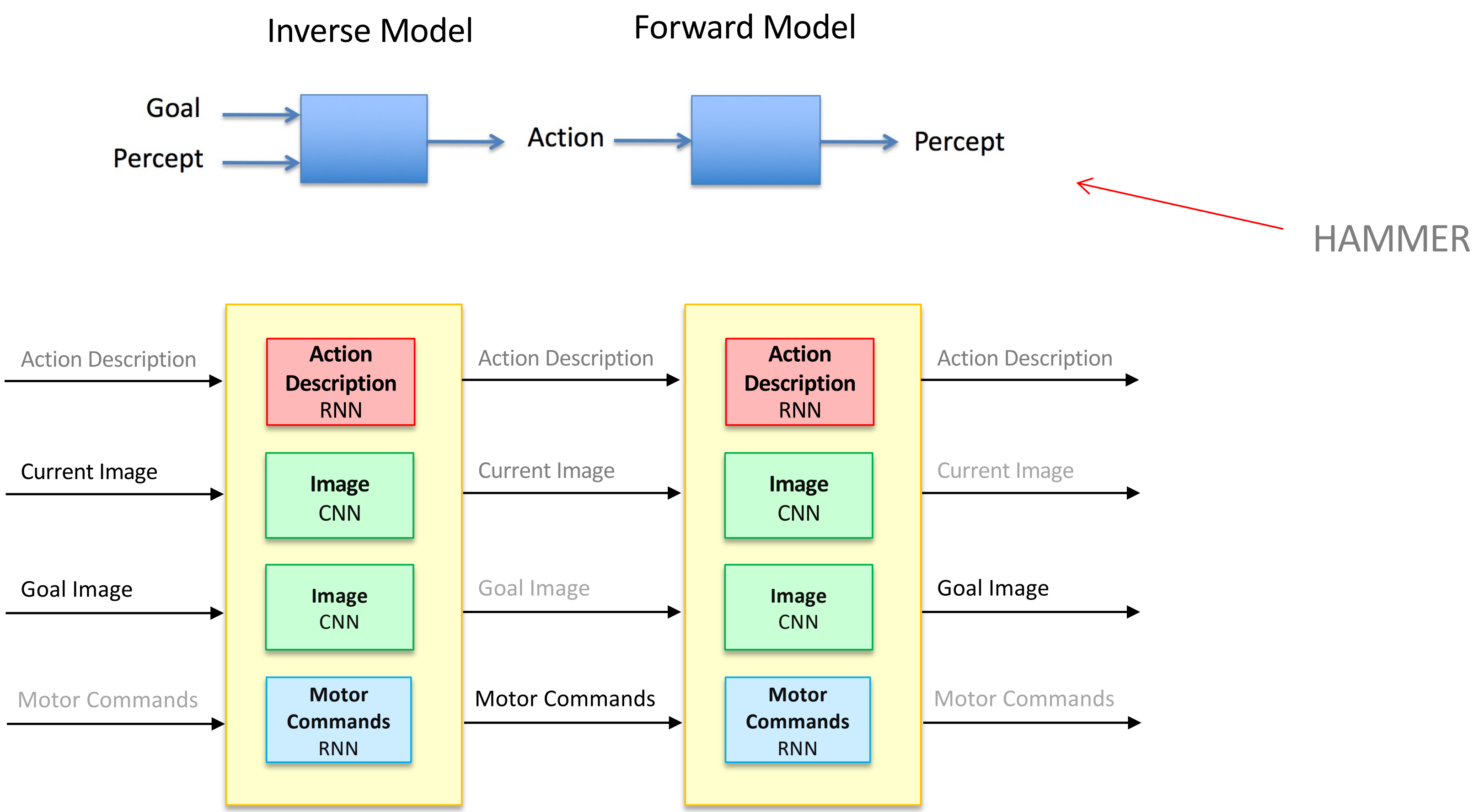
Inverse Model

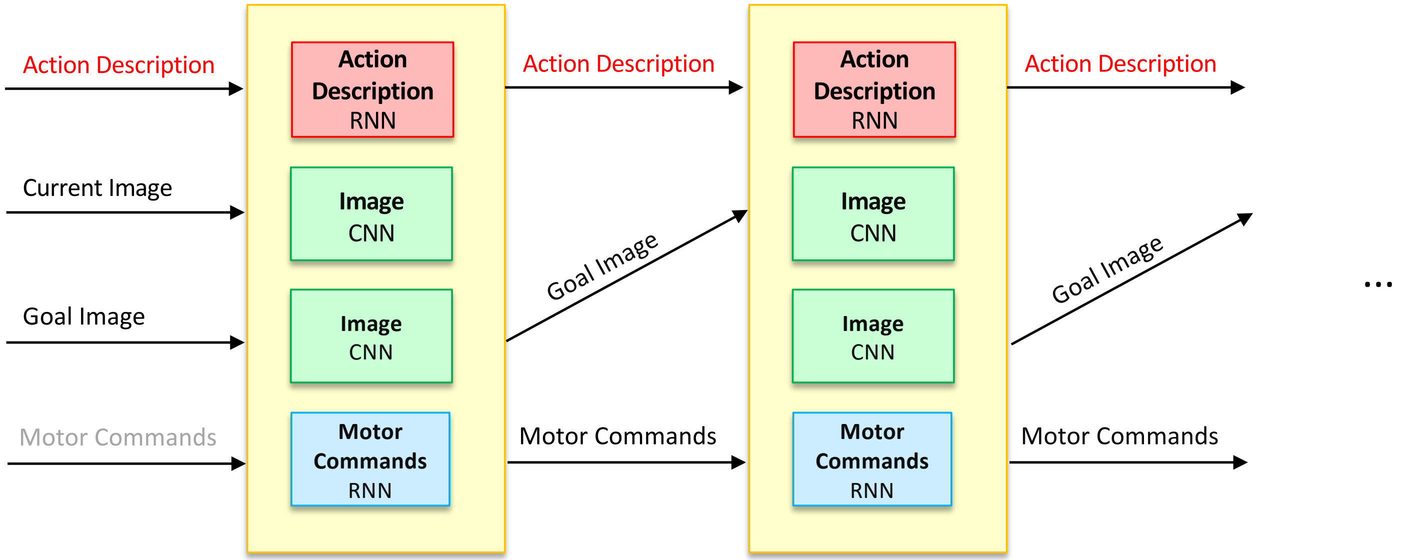




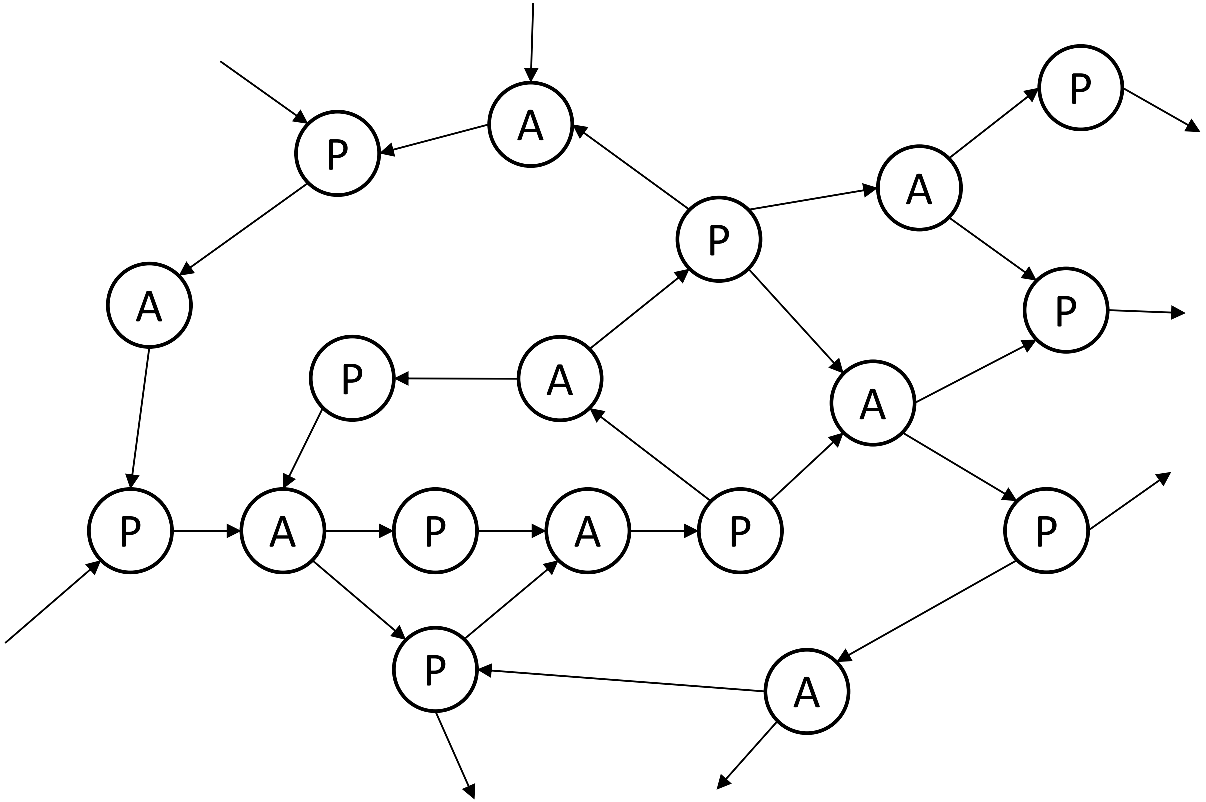
Inverse Model




Inverse Model
Forward Model
Goal
Percept
Action
Percept
HAMMER
Action Description
Current Image
Goal Image
Motor Commands
Action Description RNN
Image CNN
Image CNN
Motor Commands RNN
Action Description
Current Image
Goal Image
Motor Commands
Action Description RNN
Image CNN
Image CNN
Motor Commands RNN
Action Description
Current Image
Goal Image
Motor Commands


Action Description
Current Image
Goal Image
Motor Commands
Action Description RNN
Image CNN
Image CNN
Motor Commands RNN
Action Description
Goal Image
Motor Commands
Action Description RNN
Image CNN
Image CNN
Motor Commands RNN
Action Description
Goal Image
Motor Commands
...

Joint Episodic-Procedural Memory



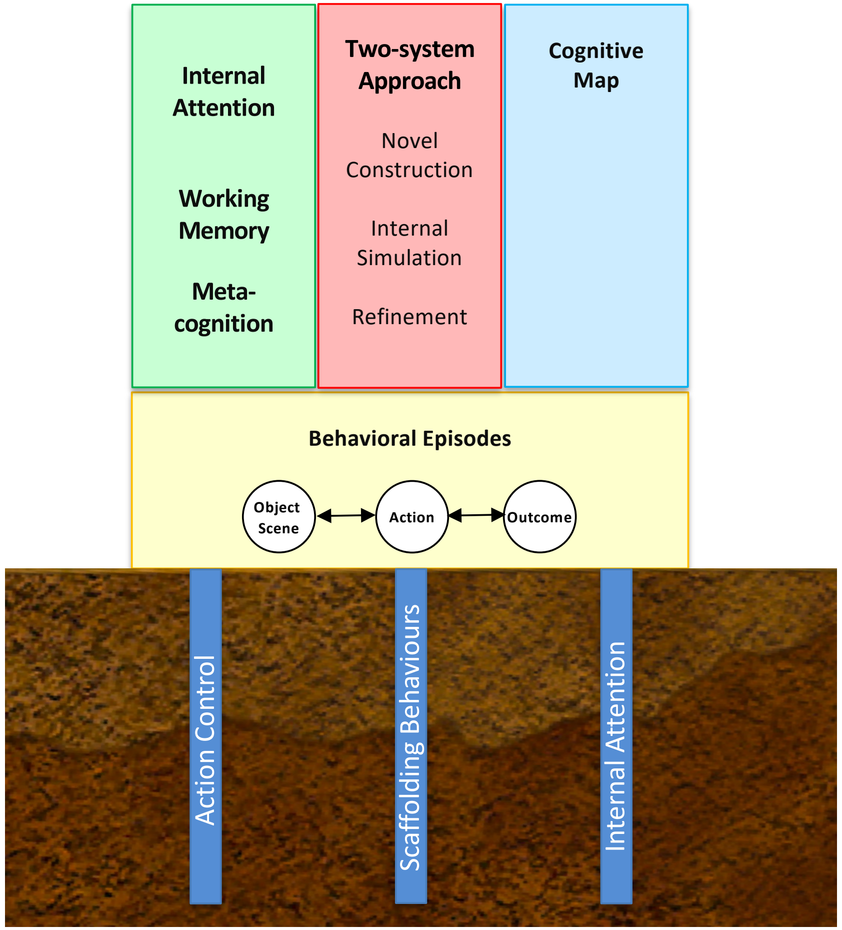
[D.Vernon, M.Beetz, and G.Sandini. Prospection in cognitive robotics: The case for joint episodic-procedural memory. Frontiers in Robotics and AI, 2(Article 19):1–14, 2015.]

Challenges for cognitive architectures and the situation model framework

1. Decomposition, reconstruction, and recombination of behavioural episodes
2. Hierarchical behavioural episodes
3. Networks of behavioural episodes
4. Multiple levels of abstraction in internal simulation
5. Multiple timescales in internal simulation
6. Situation models vs. cognitive maps
7. Context sensitivity: what criteria are used for attention?
8. Autonomy: extrinsic vs. intrinsic goals

It all hinges on the perceptuo-motor representation … the behavioural episode

Situation Model Framework



Thank you for your attention!

Thanks again to the ZiF

(Special thanks to Helge, Werner, Josefine, and Shiau-Chuen)

The Situation Model Framework:
Implications for the Design of Cognitive Architectures

Cognitive Behavior of Humans, Animals, and Machines: Situation Model Perspectives

ZiF Zentrum für interdisziplinäre Forschung
Center for Interdisciplinary Research

2 July 2020

David Vernon
Carnegie Mellon University Africa

www.vernon.eu