Introduction to Cognitive Robotics

Module 7: Cognitive Architectures

Lecture 3: Example cognitive architectures: ISAC

David Vernon
Carnegie Mellon University Africa

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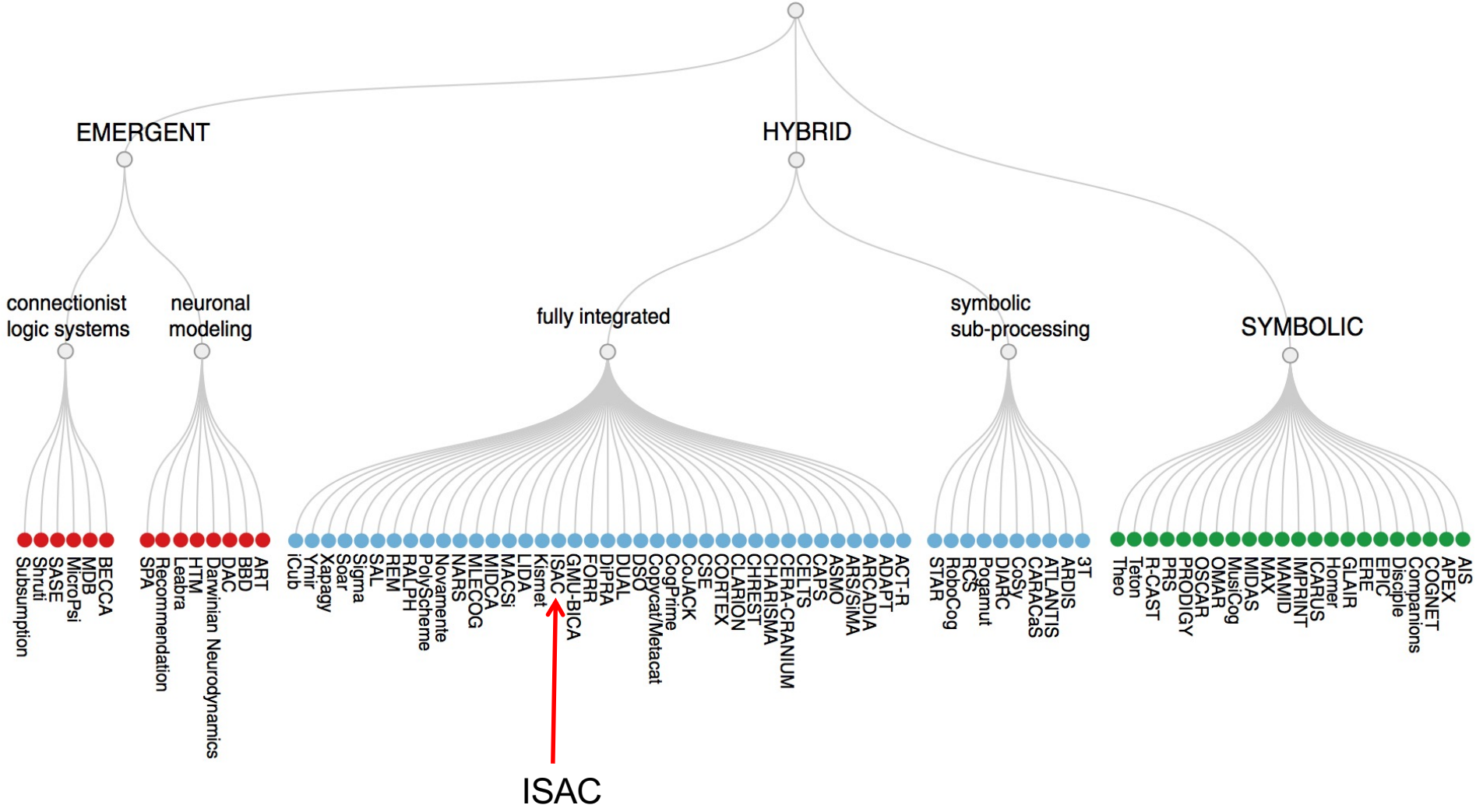
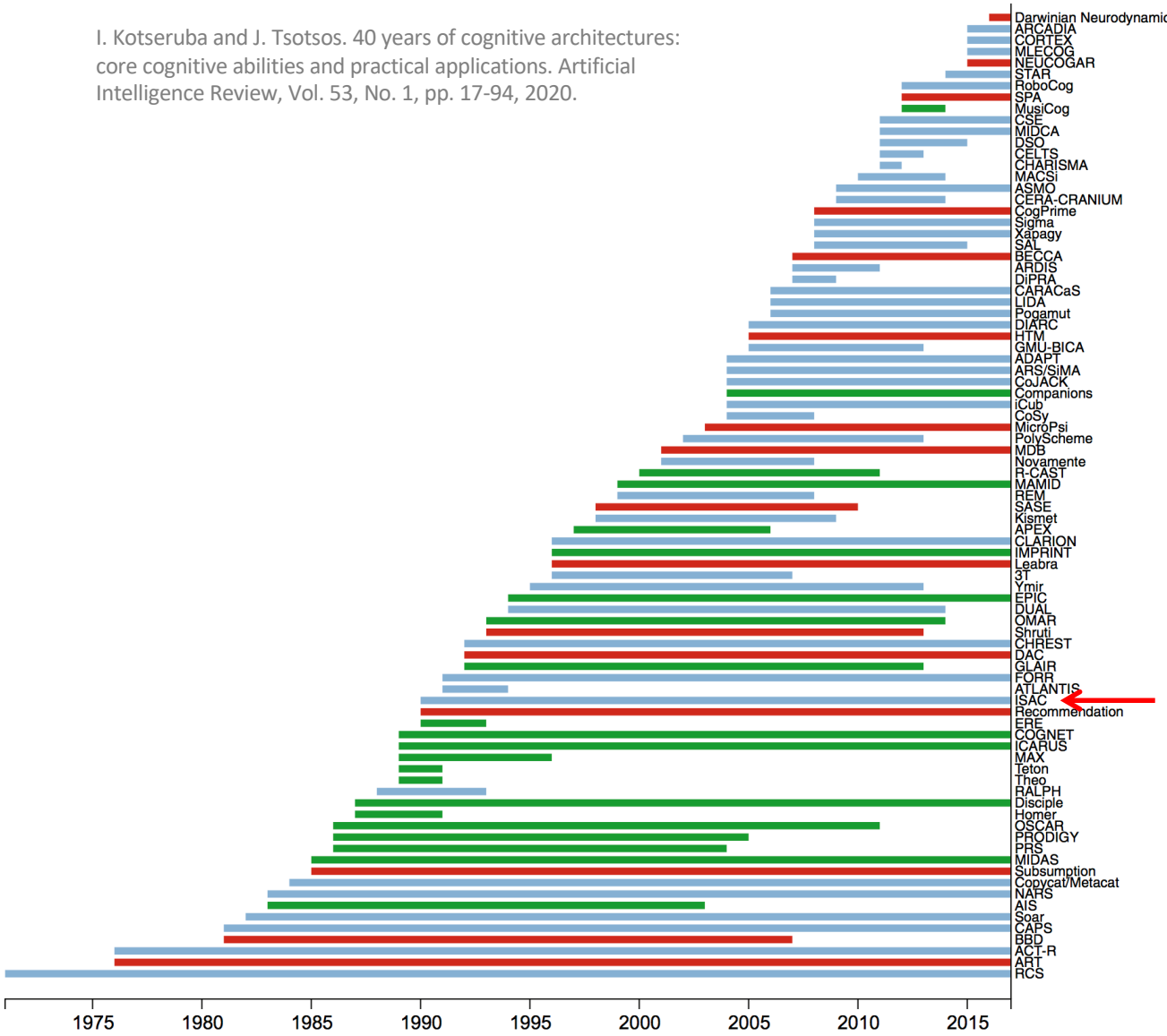
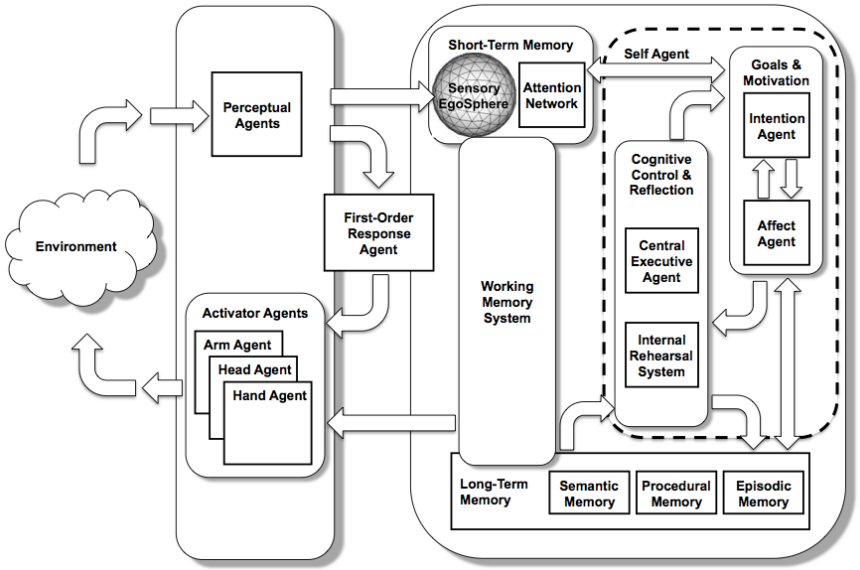


We will now study one of these cognitive architectures in a little more detail

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.



ISAC



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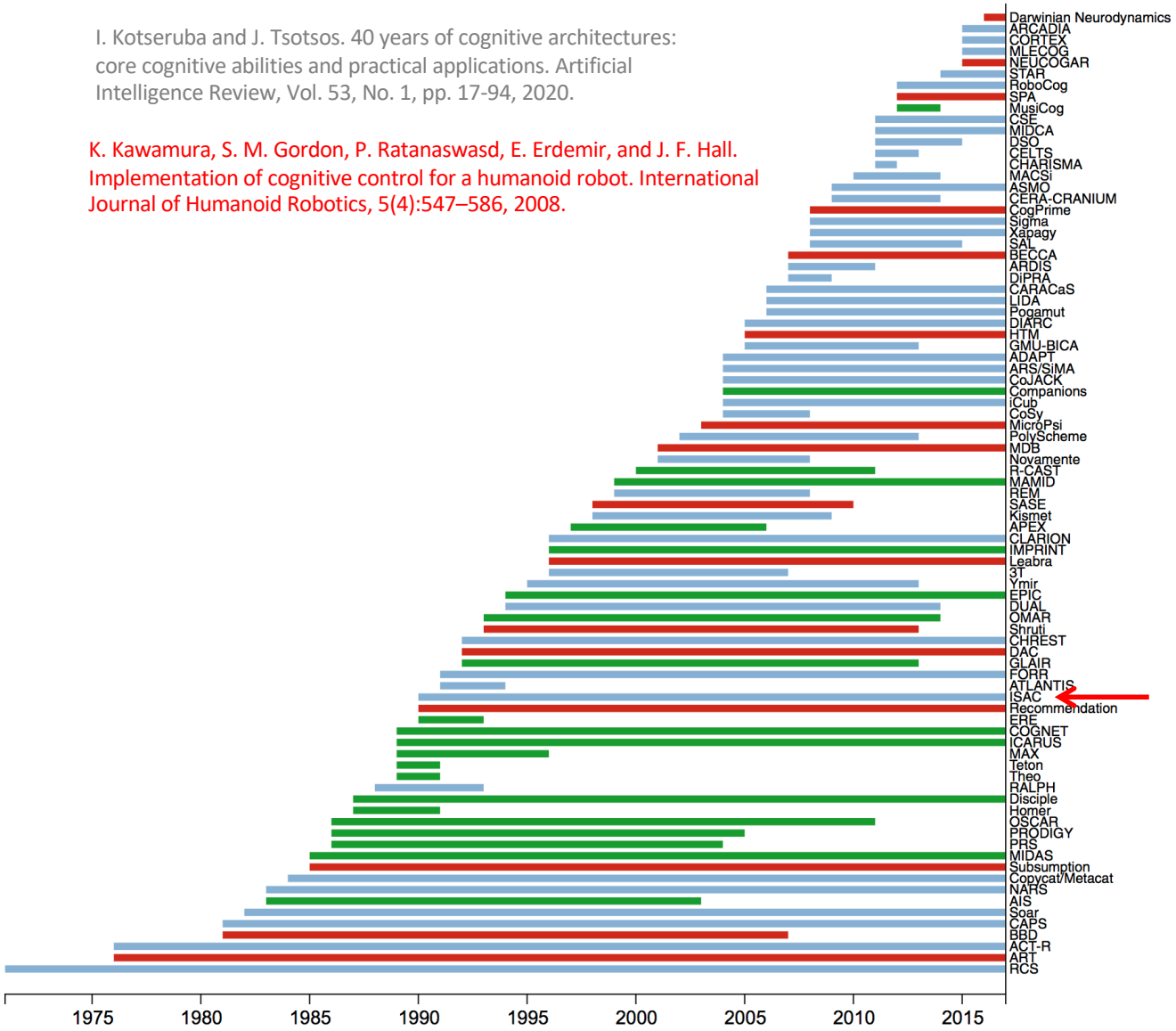
K. Kawamura, S. M. Gordon, P. Ratanaswasd, E. Erdemir, and J. F. Hall. Implementation of cognitive control for a humanoid robot. International Journal of Humanoid Robotics, 5(4):547–586, 2008.



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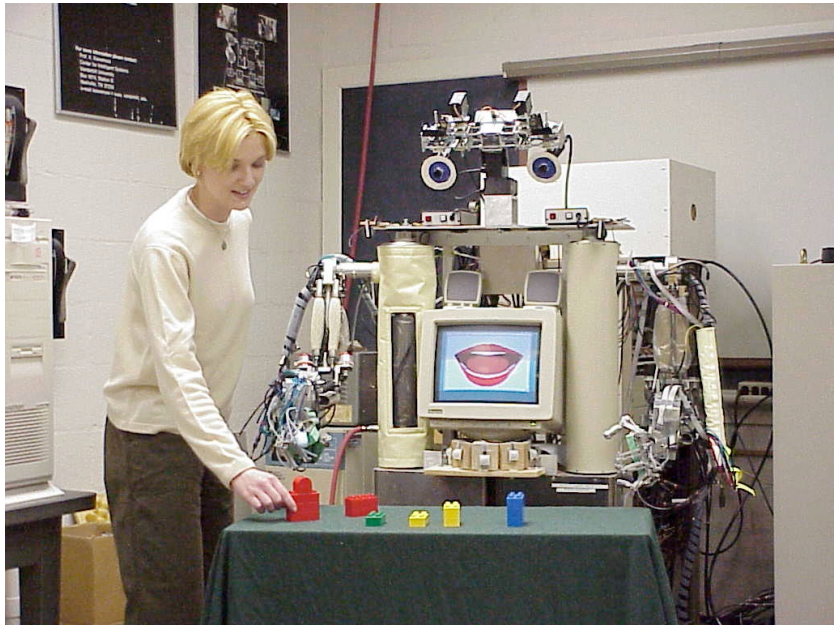
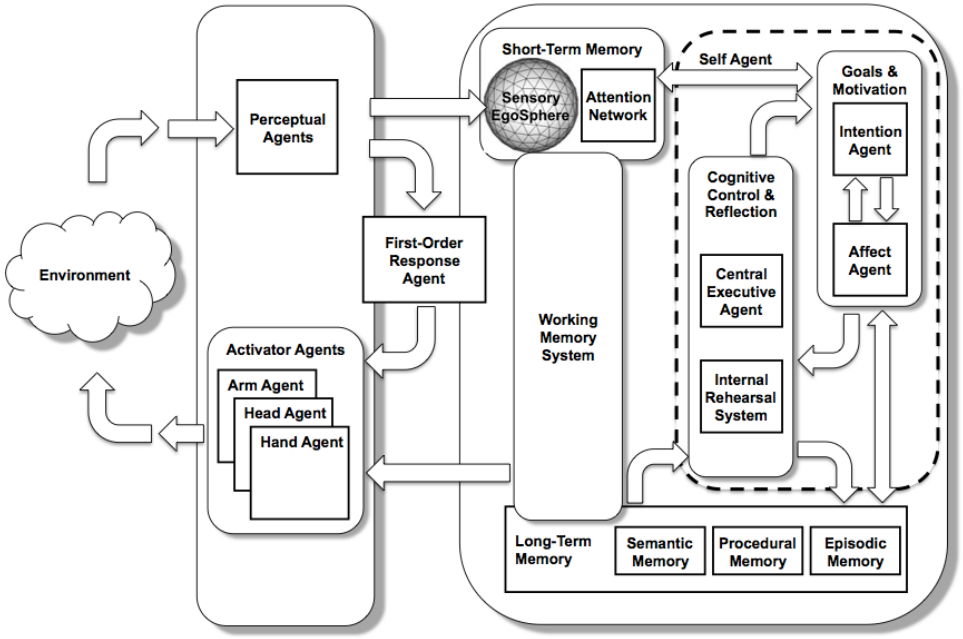


ISAC

ISAC — Intelligent Soft Arm Control

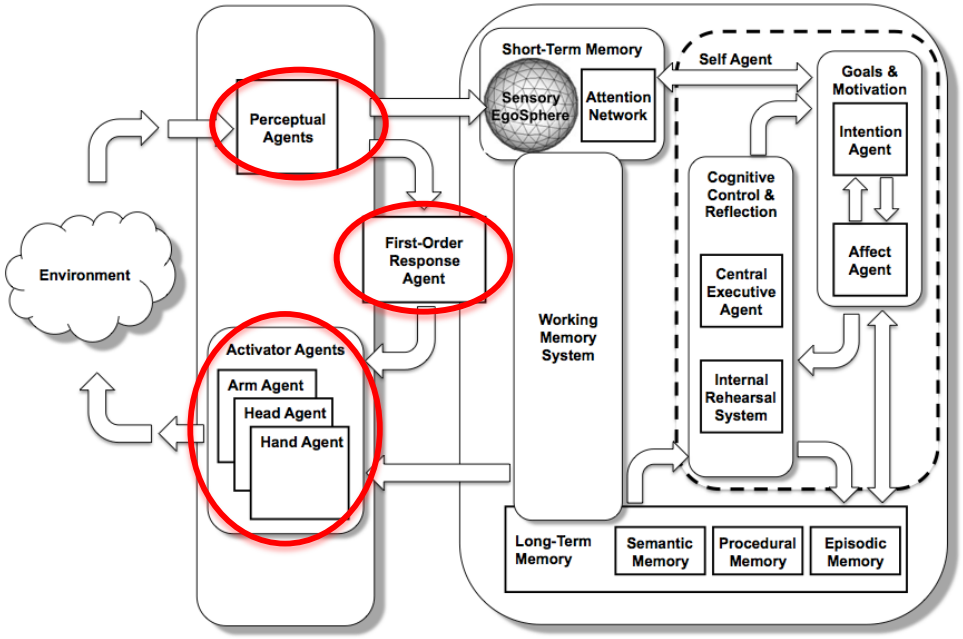
- Hybrid cognitive architecture for an upper torso humanoid robot (also called ISAC)
- Comprises an integrated collection of software agents and associated memories
- Agents operate asynchonously and communicate with each other by message passing



ISAC

Comprises activator agents

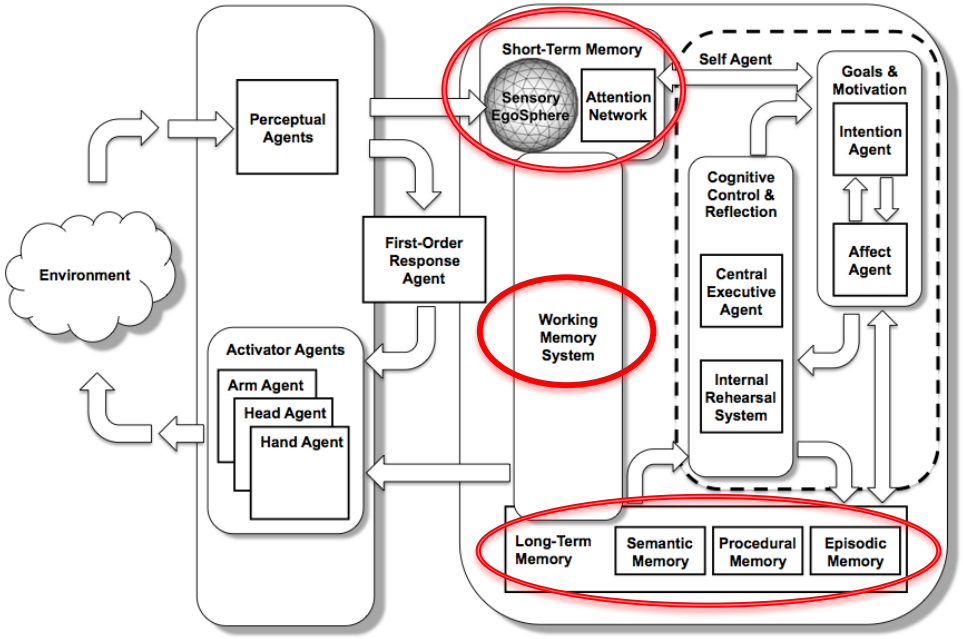
- Activator agents for motion control
- Perceptual agents
- First-order Response Agent (FRA)
  to effect reactive perception-action control



ISAC

Three memory systems

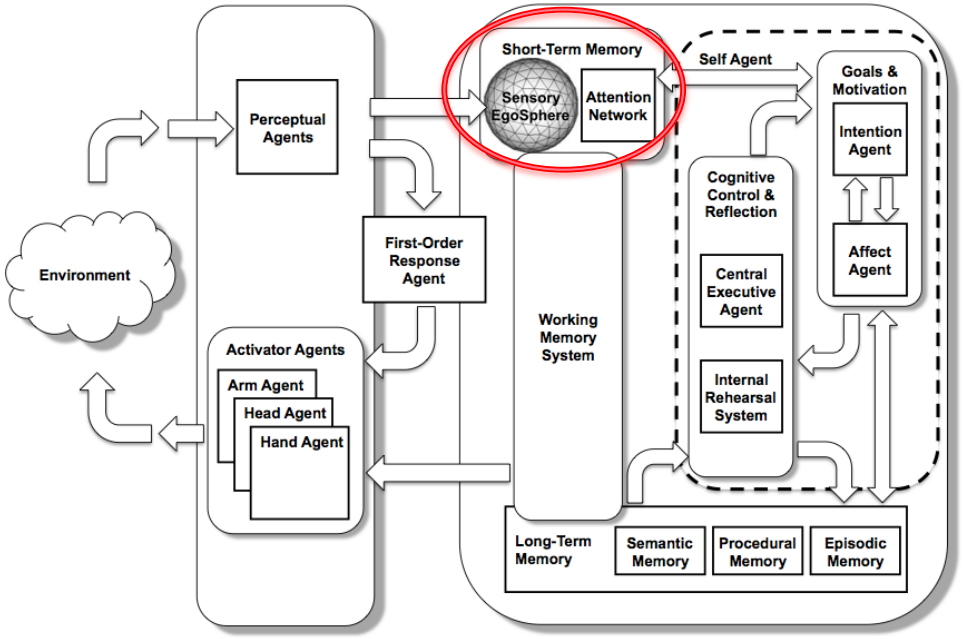
- Short-term memory (STM)
- Long-term memory (LTM)
- Working memory system (WMS)



ISAC

Short-term Memory

- Robot-centred spatio-temporal memory of the current perceptual events
- This is called a Sensory EgoSphere (SES)
  - Discrete representation of what is happening around the robot
  - Represented by a geodesic sphere indexed by two angles
- STM also has an attentional network
  - Determines the perceptual events that are most relevant



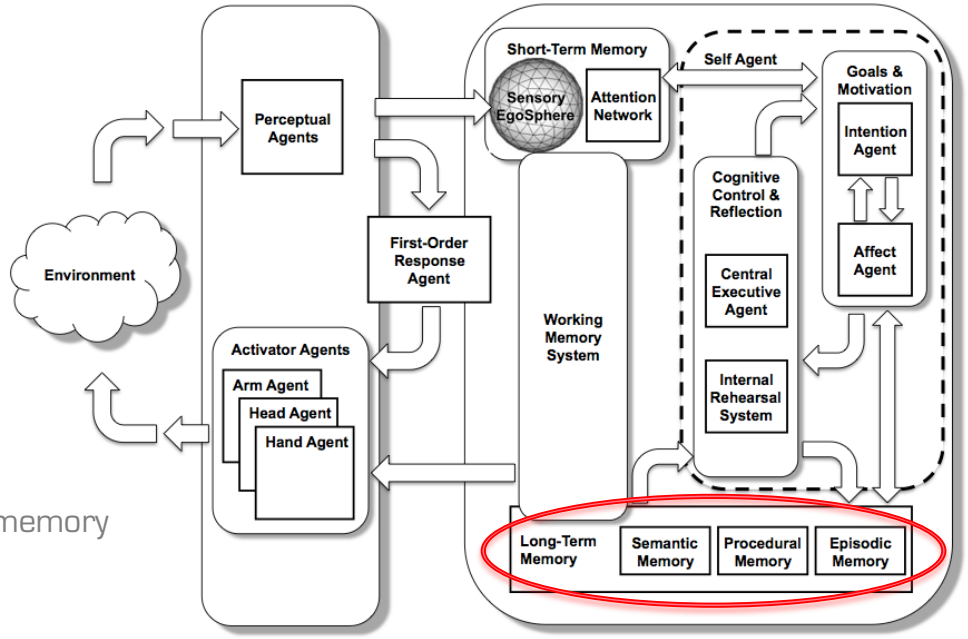
ISAC

Long-term Memory

- Stores information about the robot's learned skills and past experiences
- Semantic memory
- Episodic memory
- Procedural memory

Robot's declarative memory of the facts it knows

Representations of the motions it can perform



ISAC

Episodic memory

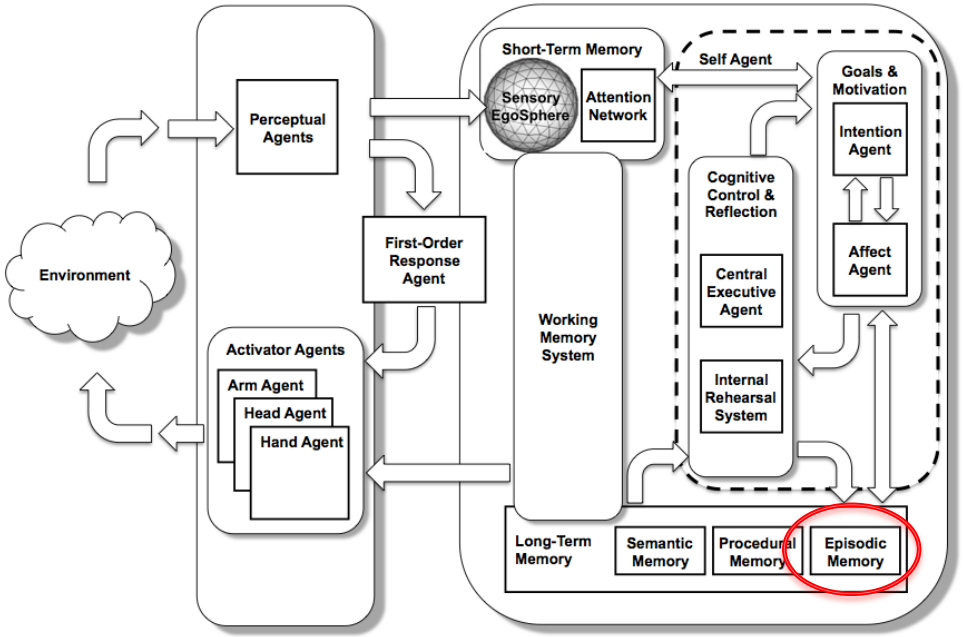
Abstracts past experiences & creates links or associations between them

i.e. task-relevant percepts from the SES

- External situation
- Goals
- Emotions
- Actions
- Outcomes that arise from actions
- Valuations of these outcomes

i.e. internal evaluation of the perceived situation

e.g. how close they are to the desired goal state and any reward received at a result

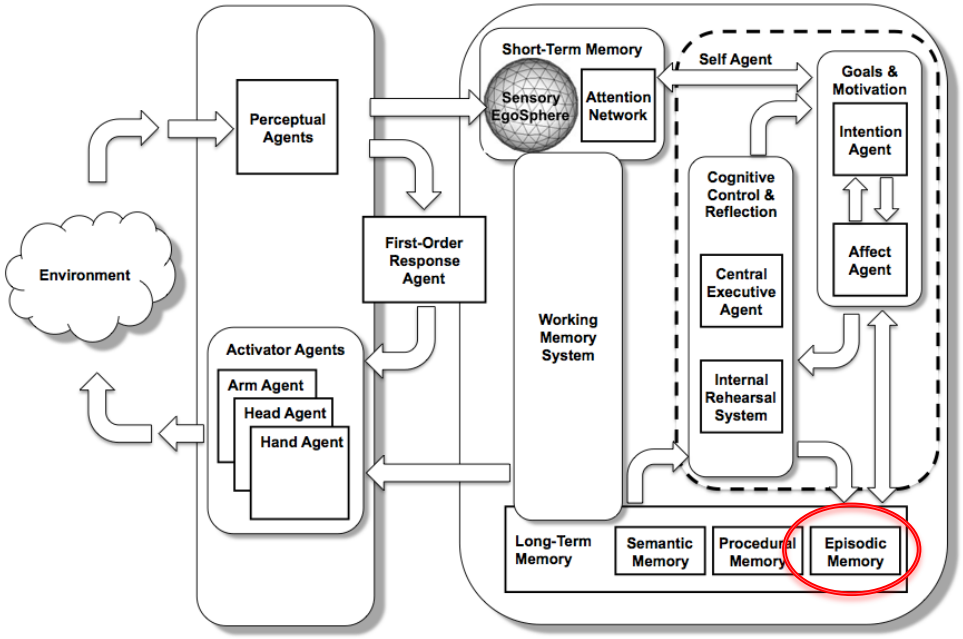


ISAC

Episodic memory

- Episodes are **connected by links** that encapsulate behaviours as transitions from one episode to another

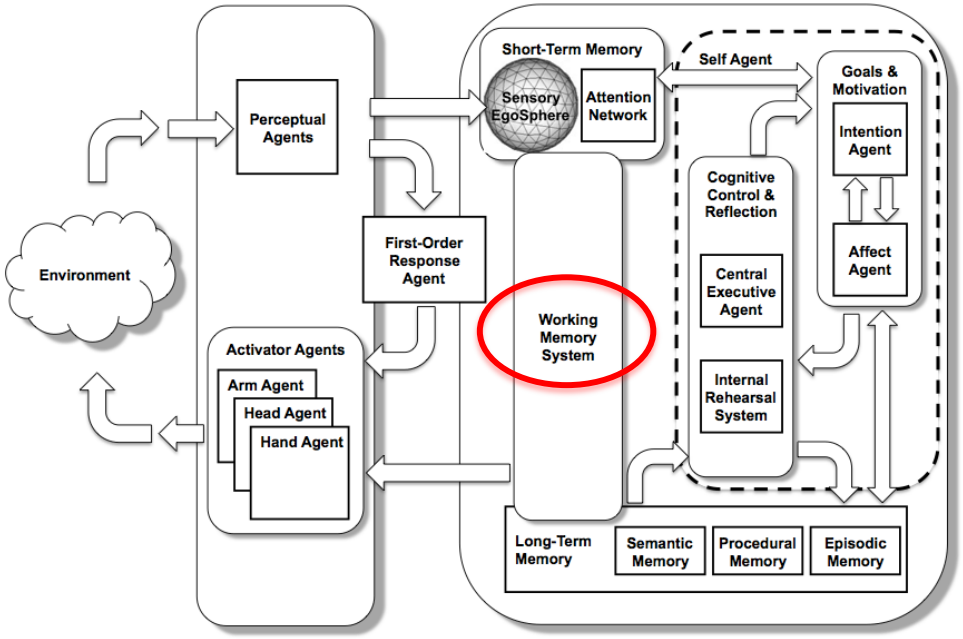
- Multi-layered



ISAC

Working Memory System

- Temporarily stores information that is related to the task currently being executed
- A type of cache memory for STM and the information it stores, called chunks
- Encapsulates expectations of future reward (learned using a neural network)



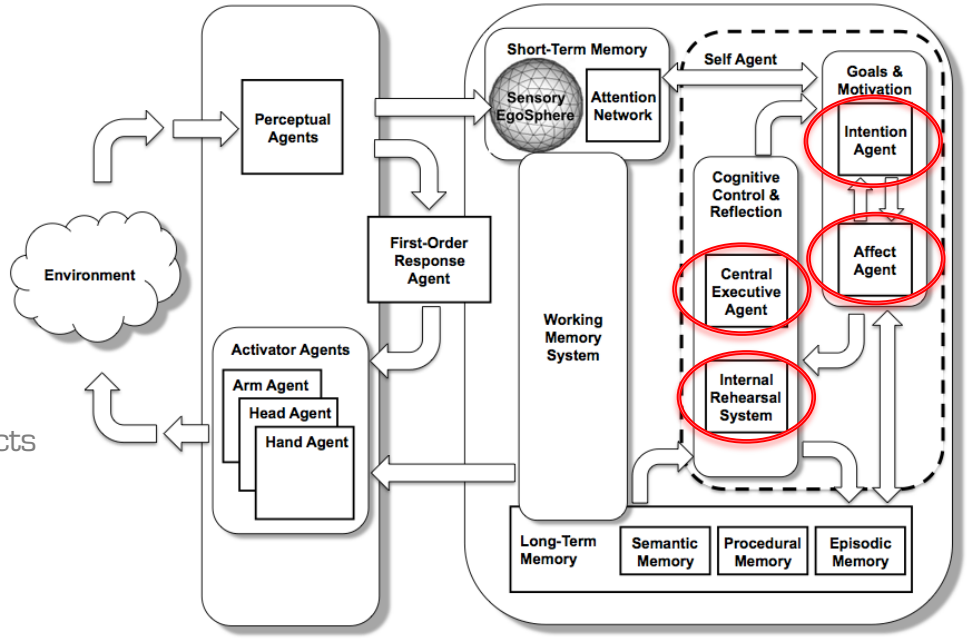
ISAC

Cognitive behaviour is achieved through the interaction of several agents

- Cognitive Control & Reflection sub-system
  - **Central Executive Agent** (CEA)
  - **Internal Rehearsal System**

Simulates the effects of possible actions

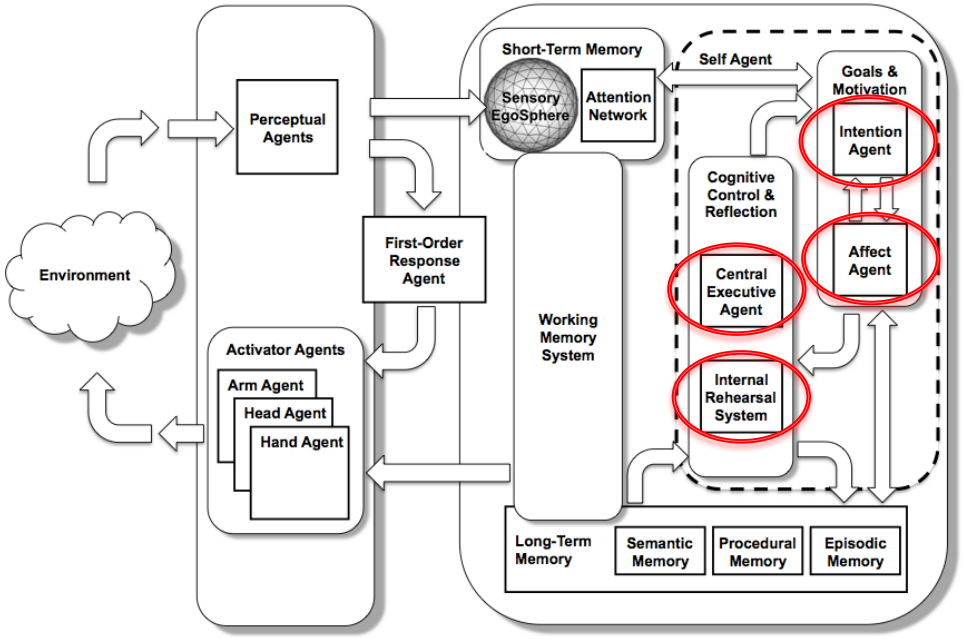
- Goals & Motivation sub-system
  - **Intention Agent**
  - **Affect Agent**



ISAC

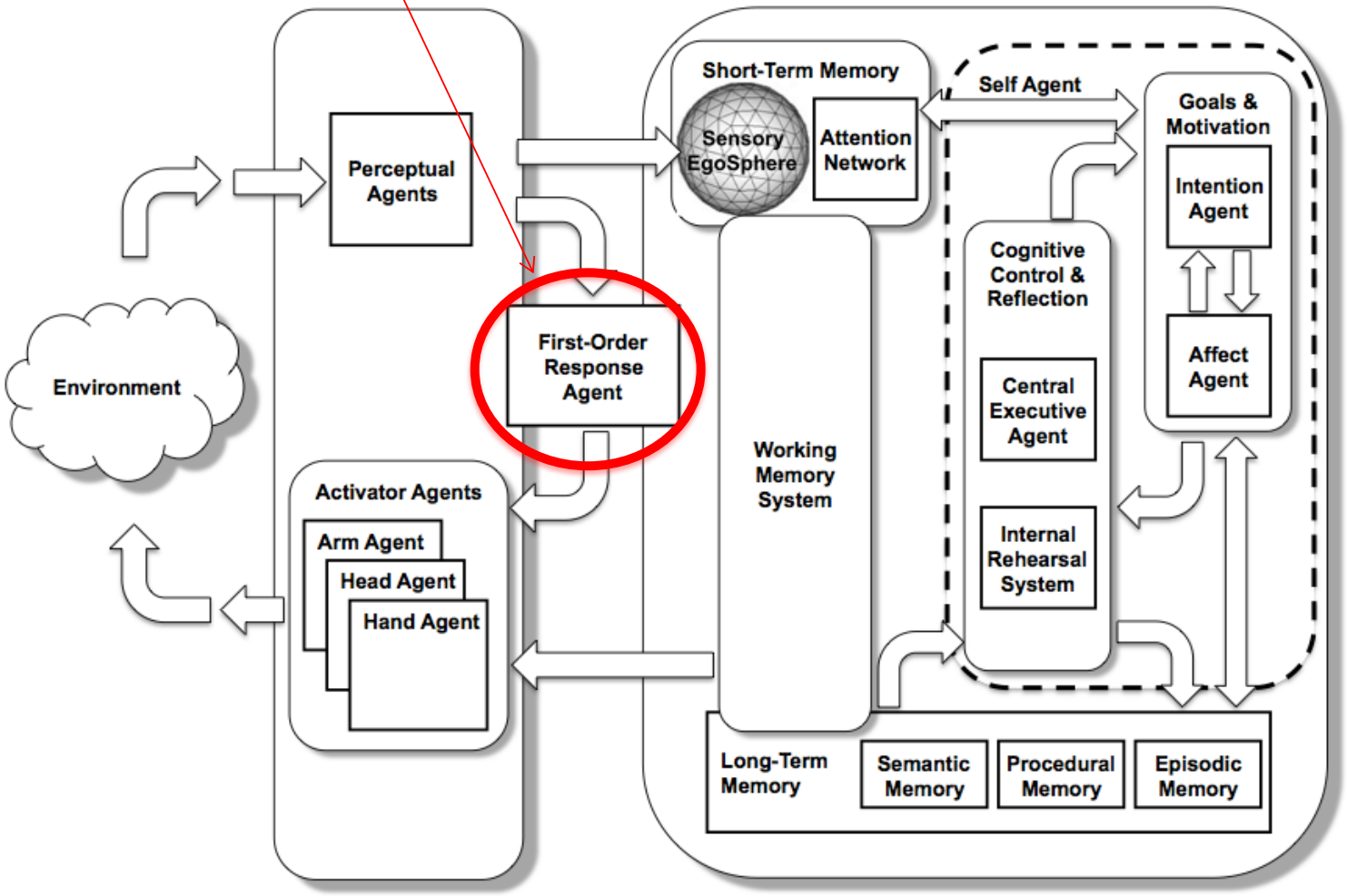
Cognitive behaviour is achieved through the interaction of several agents

- The CEA is responsible for cognitive control
- Invokes the skills required to perform some given task on the basis of the current focus of attention and past experiences
- The goals are provided by the Intention Agent
- Decision-making is modulated by the Affect Agent



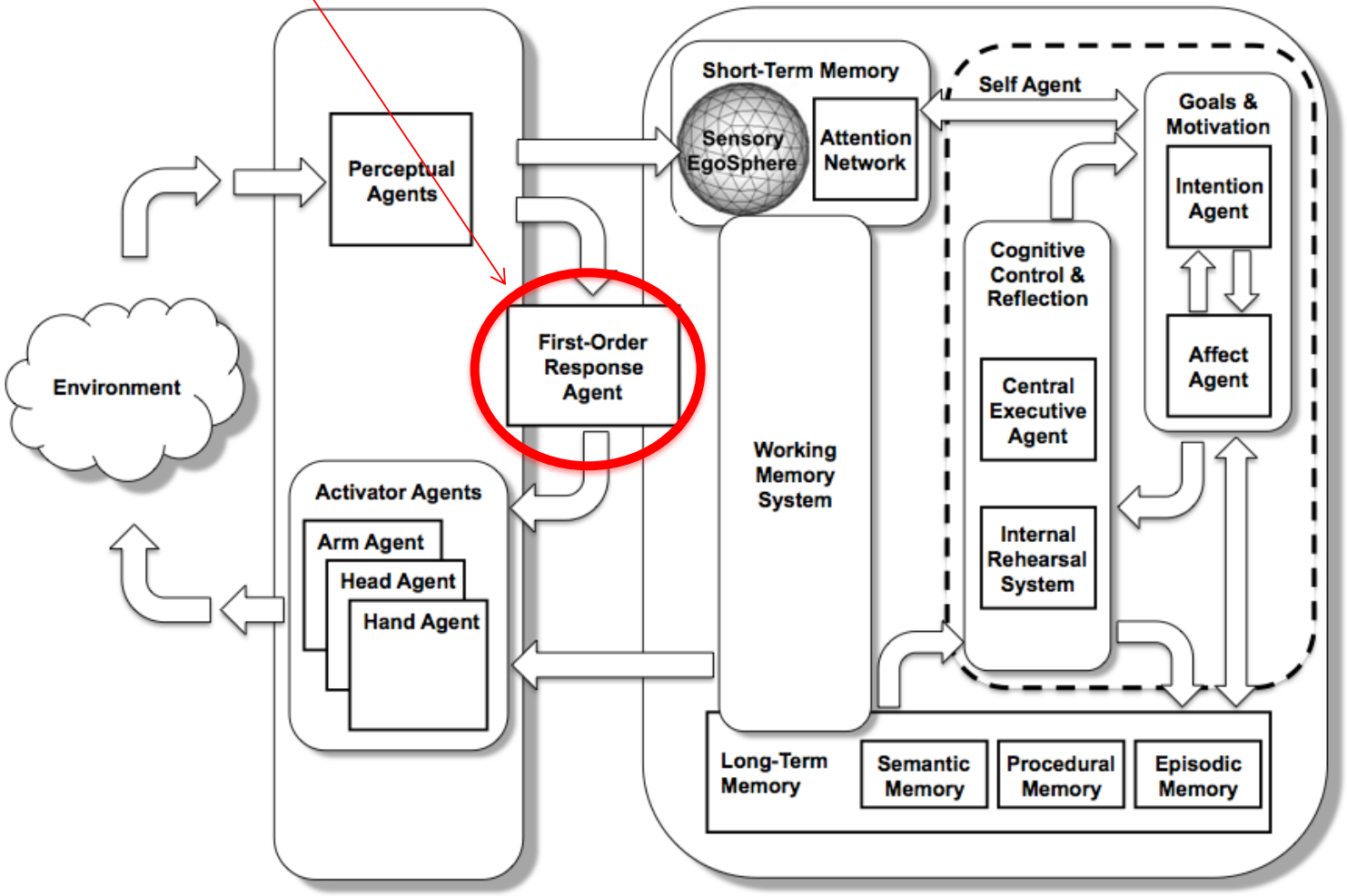
Normally, the First-order Response Agent (FRA) produces reactive responses to sensory triggers

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

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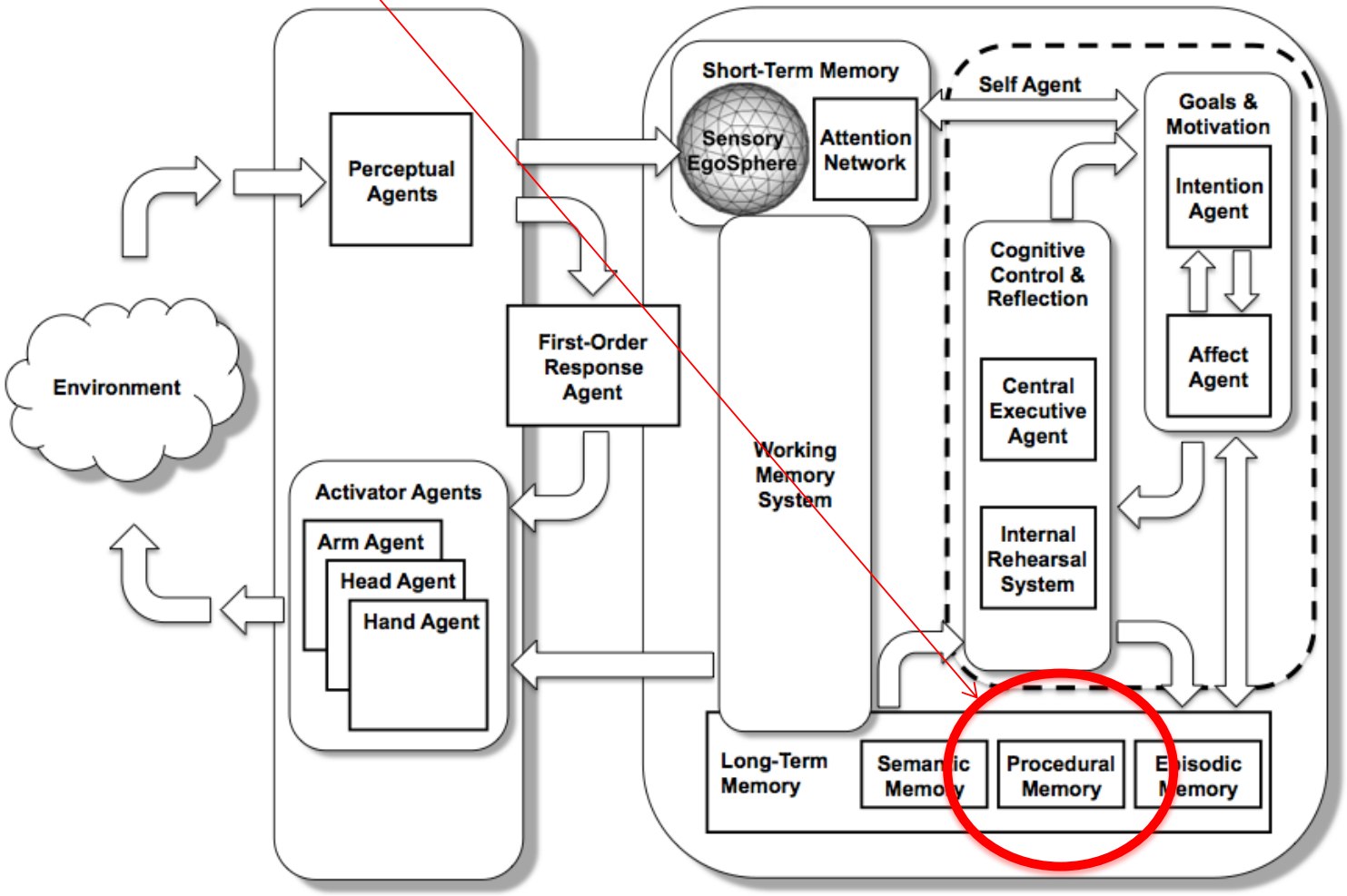
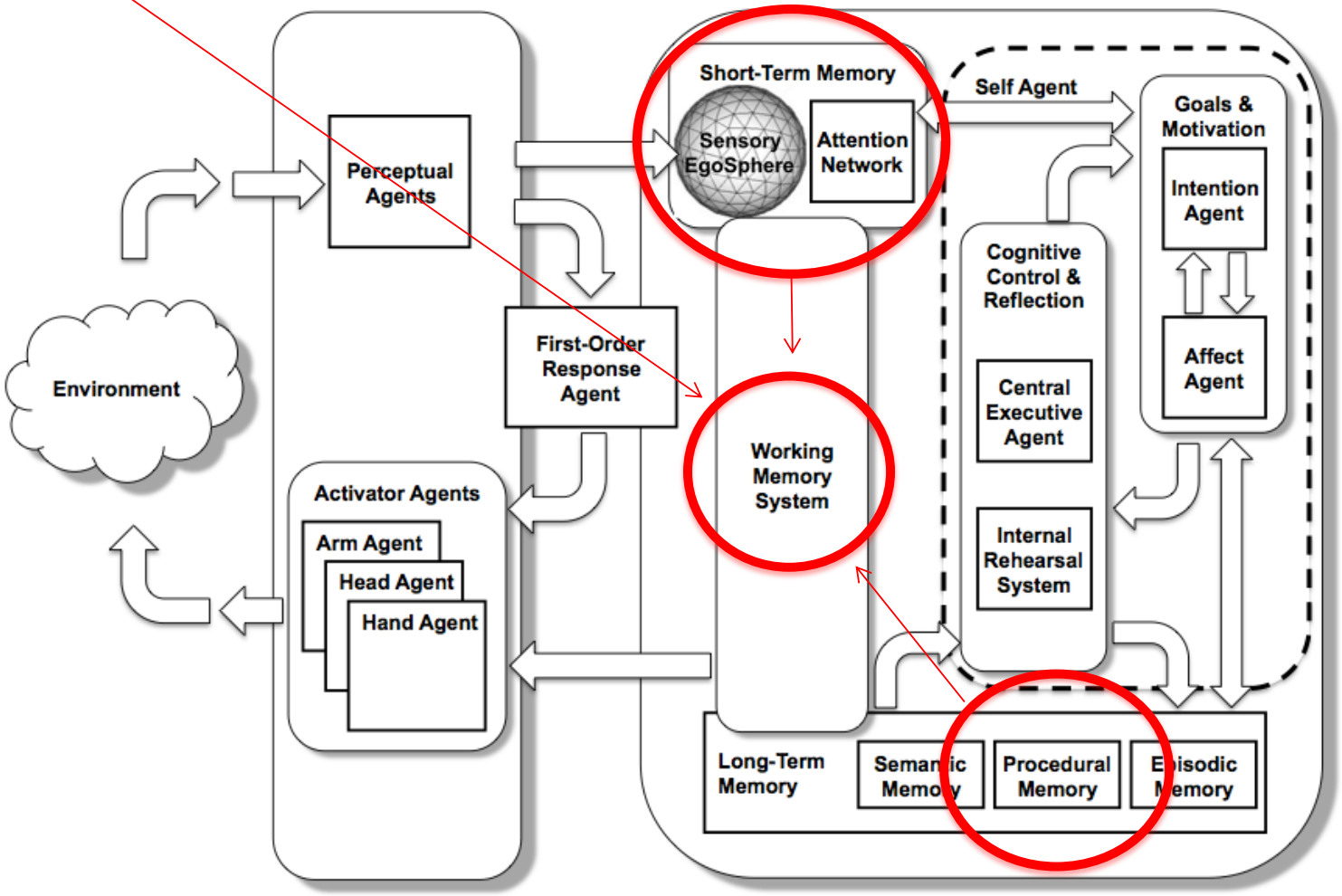


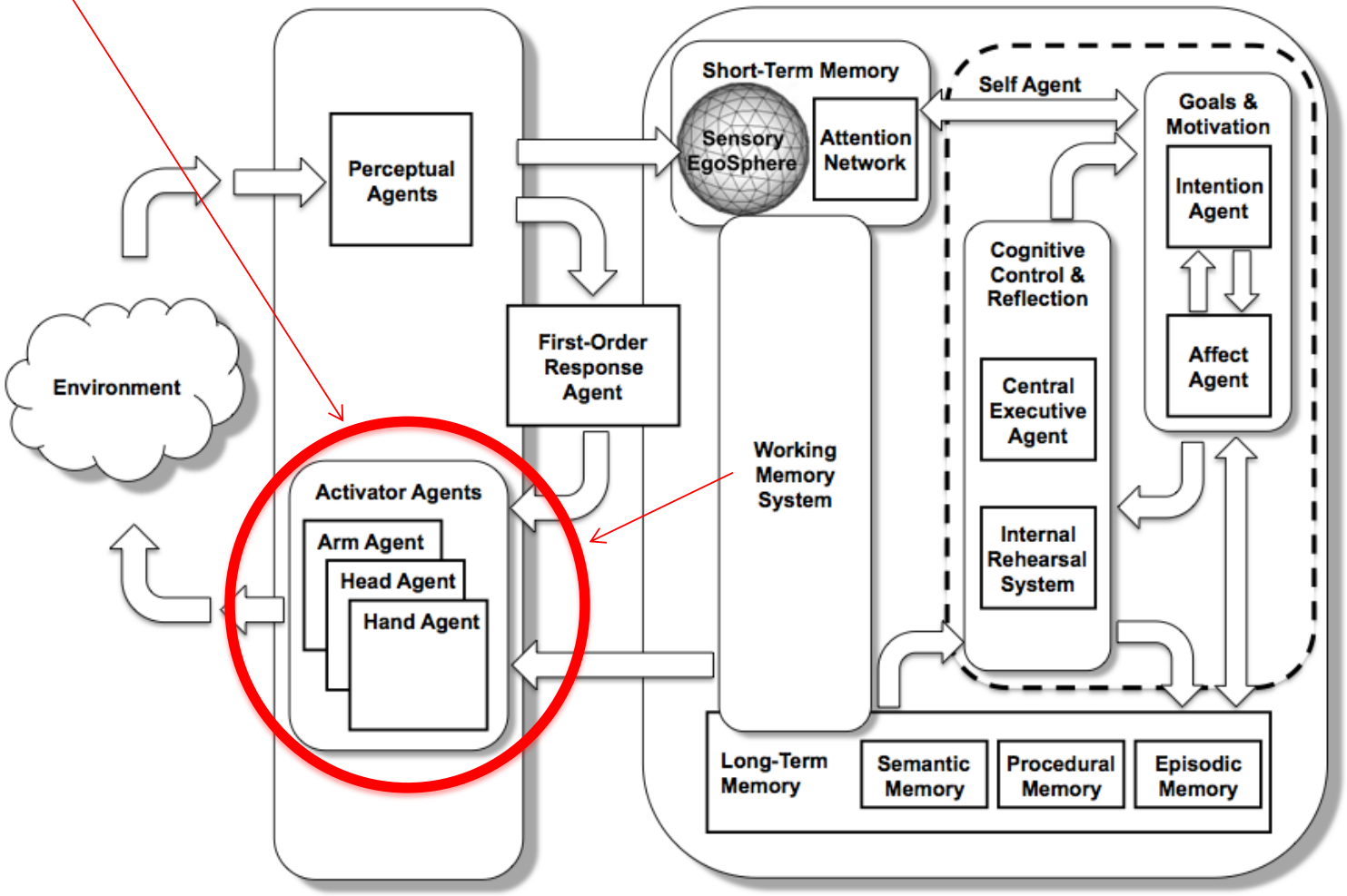
It then places it in the WMS as chunks along with the current percept

ISAC



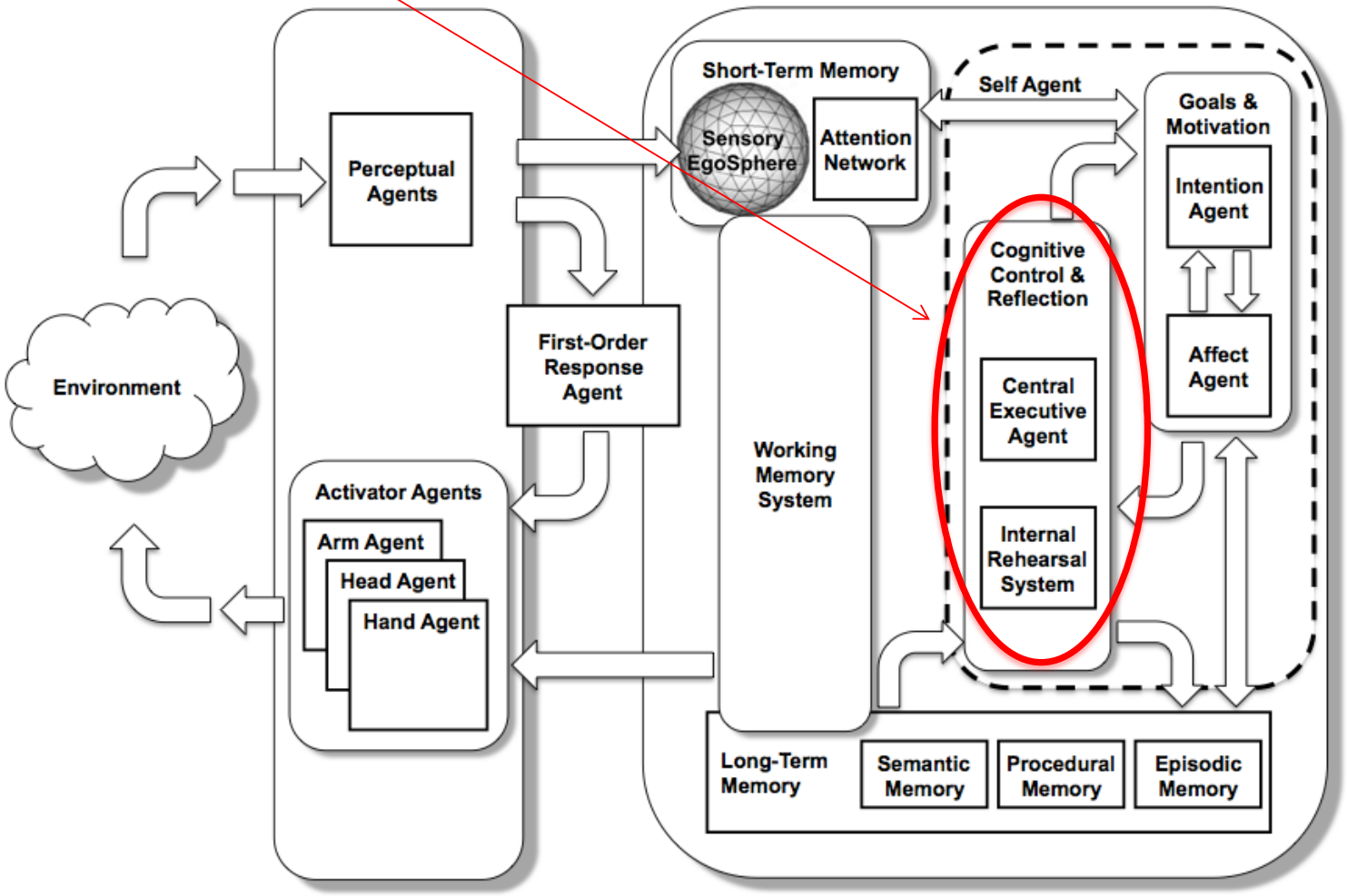
The Activator Agent then executes it, suspending execution whenever a reactive response is required

ISAC



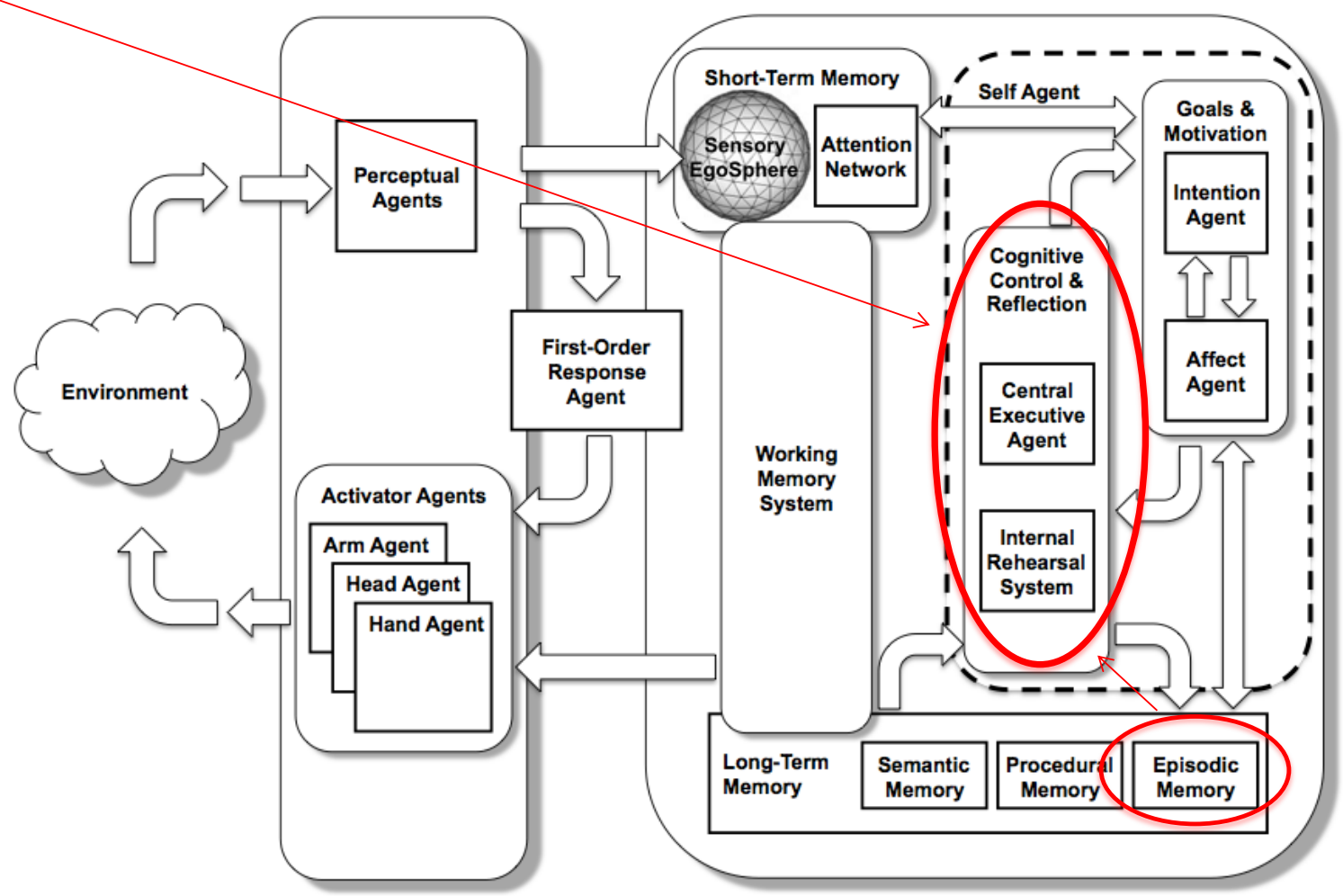
If the FRA finds no matching skill for the task, the Central Executive Agent takes over

ISAC



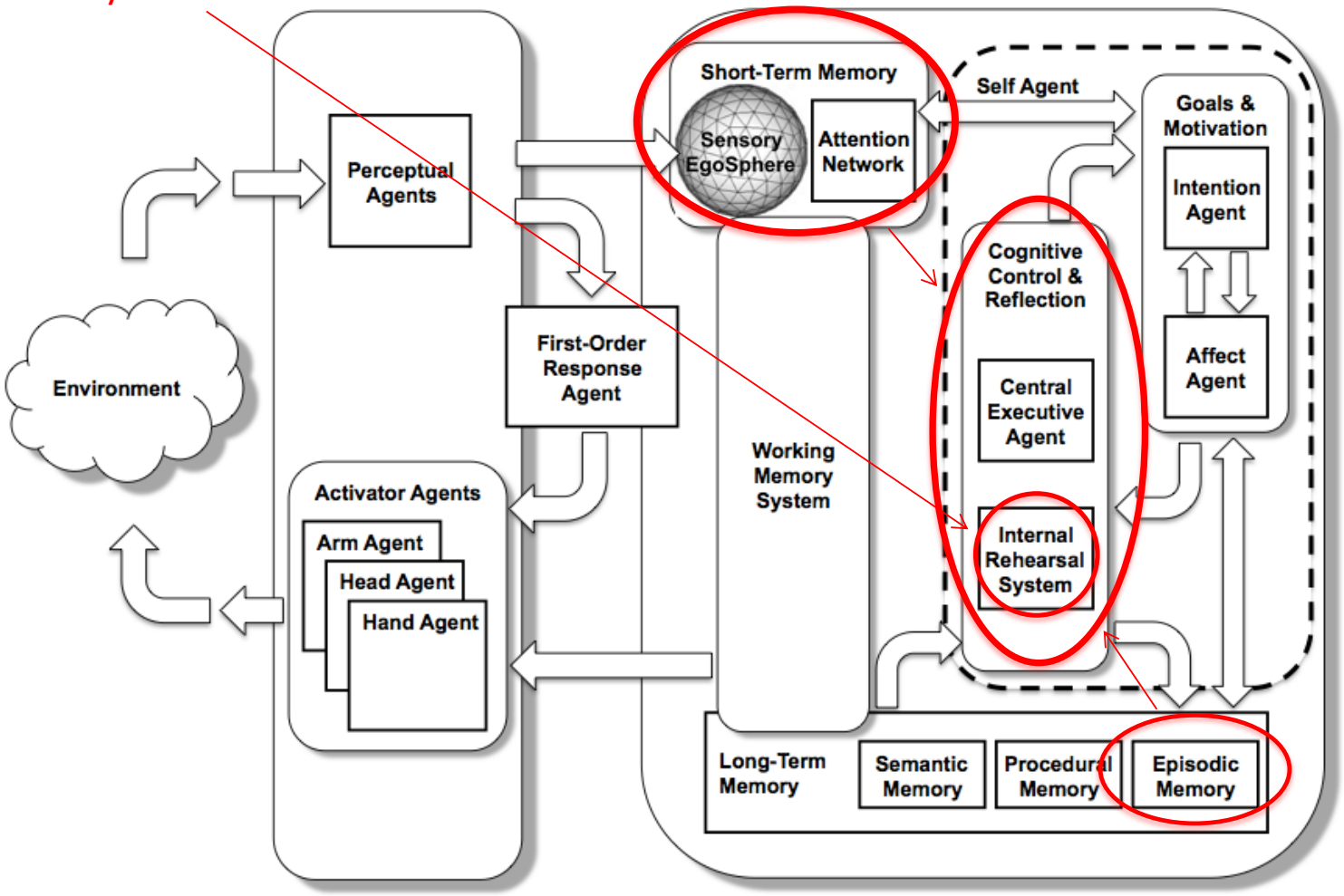
Recalls from episodic memory past experiences and behaviours that contain information similar to the current task

ISAC

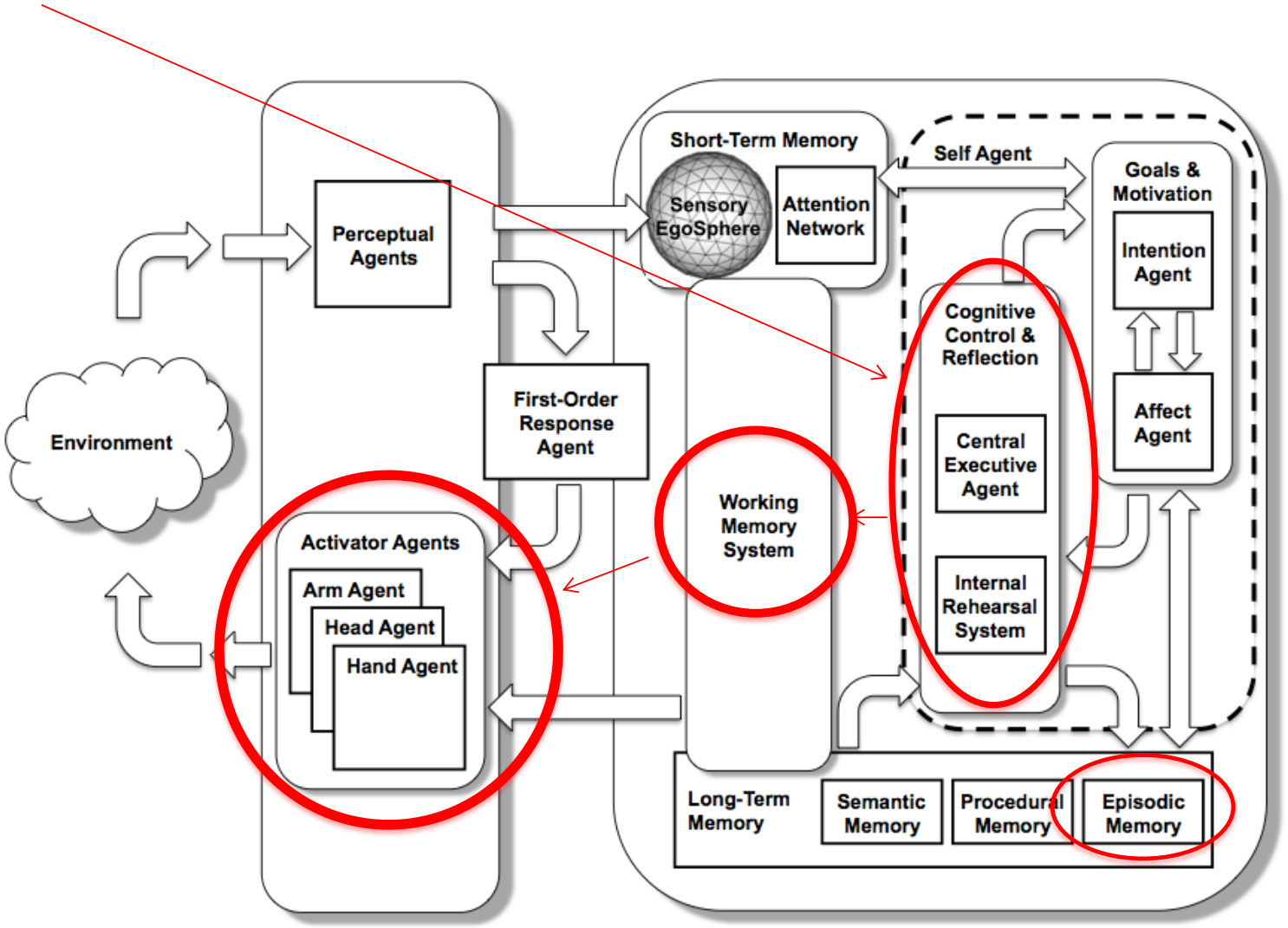


Select a behaviour-percept pair,
based on the current percept in the SES,
its relevance, and the likelihood of successful
execution as determined by internal simulation

ISAC



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



Recommended Reading

D. Vernon, Artificial Cognitive Systems – A Primer, MIT Press, 2014; Chapter 3.

D. Vernon, Cognitive Architectures, in Cognitive Robotics, A. Cangelosi and M. Asada, MIT Press, 2022.

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.

K. Kawamura, A Perspective on Cognitive Robot Research and Development, International Journal of Humanoid Robotics, 2023. https://www.worldscientific.com/doi/epdf/10.1142/S0219843623500238

I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, 2020

J. E. Laird, C. Lebiere, and P. S. Rosenbloom, “A standard model of the mind: toward a common computational framework across artificial intelligence, cognitive science, neuroscience, and robotics”, AI Magazine, Vol. 38, pp. 13-26.

D. Vernon, C. von Hofsten, and L. Fadiga. "A Roadmap for Cognitive Development in Humanoid Robots", Cognitive Systems Monographs (COSMOS), Vol. 11, Springer, 2010; Chapter 5 and Appendix A.

Recommended Videos

Daniel Wolpert, Columbia University: The Real Reason for Brains
https://www.youtube.com/watch?v=7s0CpRfyYp8

John E. Laird, University of Michigan: Open Research and the Soar Cognitive Architecture
https://www.youtube.com/watch?v=2pNsfBj7XSA&feature=youtu.be

John E. Laird, University of Michigan: The Soar Cognitive Architecture: Current and Future Capabilities
https://www.youtube.com/watch?v=BUiWk-DqLaA

Kazuhiko Kawamura, Vanderbilt University: Cognitive Robotics and Control:
https://www.youtube.com/watch?v=7i_l80w2mtg

Jeffrey Krichmar, University of California: Neurorobotics: Connecting the Brain, Body and Environment
https://www.youtube.com/watch?v=rb2OQH7ghW8

Ron Sun, Rensselaer Polytechnic Institute: Clarion: A comprehensive, Integrative Cognitive Architecture
https://www.youtube.com/watch?v=HLFijuMhJWQ

Recommended Videos

These and other short videos on cognitive architectures can be found at the 2021 TransAIR Workshop on Cognitive Architectures for Robot Agents

https://transair-bridge.org/workshop-2021/