An Example Architecture Using the Storm Framework

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with Doug Pearson, Richard Lewis, and John Laird

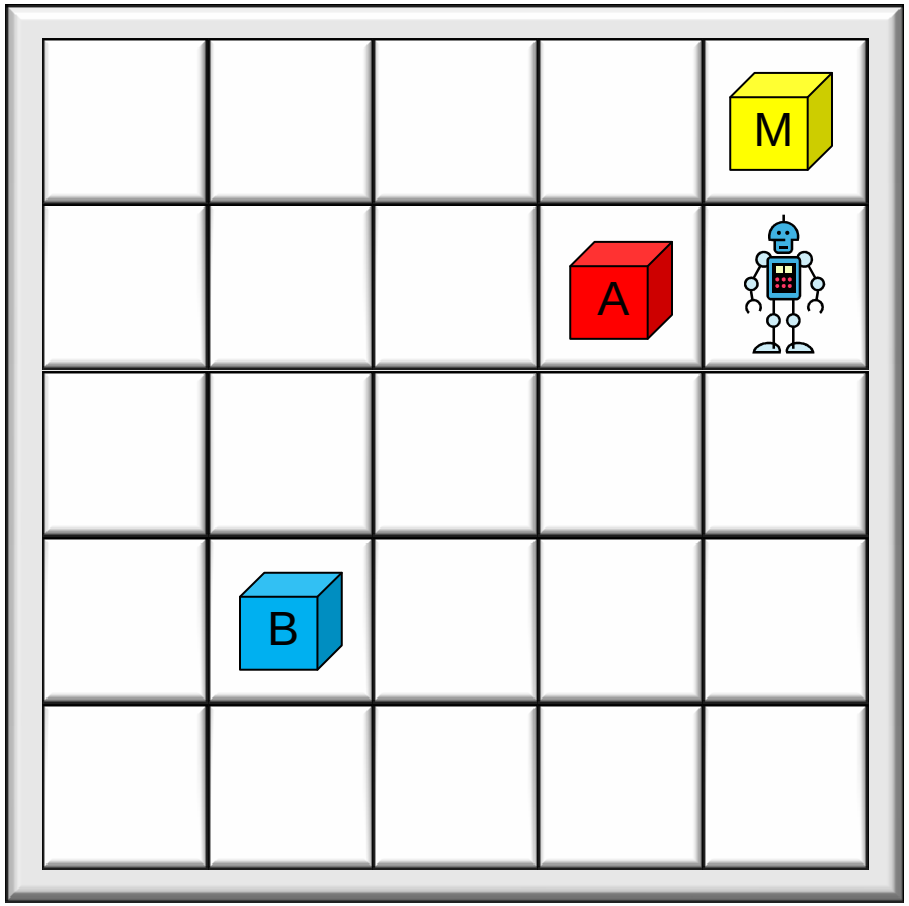
Storm Architecture Research Plan

- Long-term goal:
  - Create an architecture with brain-based algorithms that model brain structure/function
- Short-term goals:
  - Debug/test framework
  - Explore effects of various architectural commitments
  - Iteratively develop complex architectures

Iteratively More Complex Tasks

- Begin with a simple task initially
  - Requires learning selection knowledge for:
    - an external (motor) action
    - an internal (retrieval) action
- Each successive task will require a slightly more complex architecture
- As we go, experiment with the effects of various architectural commitments

Task #1 – Secret Message Task



- **Goal: Open the box identified by the message inside box M**
- **Episodic Domain**
- **Discrete state space**
- **Deterministic Actions**
- **Senses:**
  - **Current location <x,y>**
  - **Secret Message**
  - **External Reward**
- **Actions:**
  - **Move N, E, S, W**
  - **Open box**
- **Reward Structure:**
  - **+10: open correct box**
  - **-10: open wrong box**
  - **-1: every other action**

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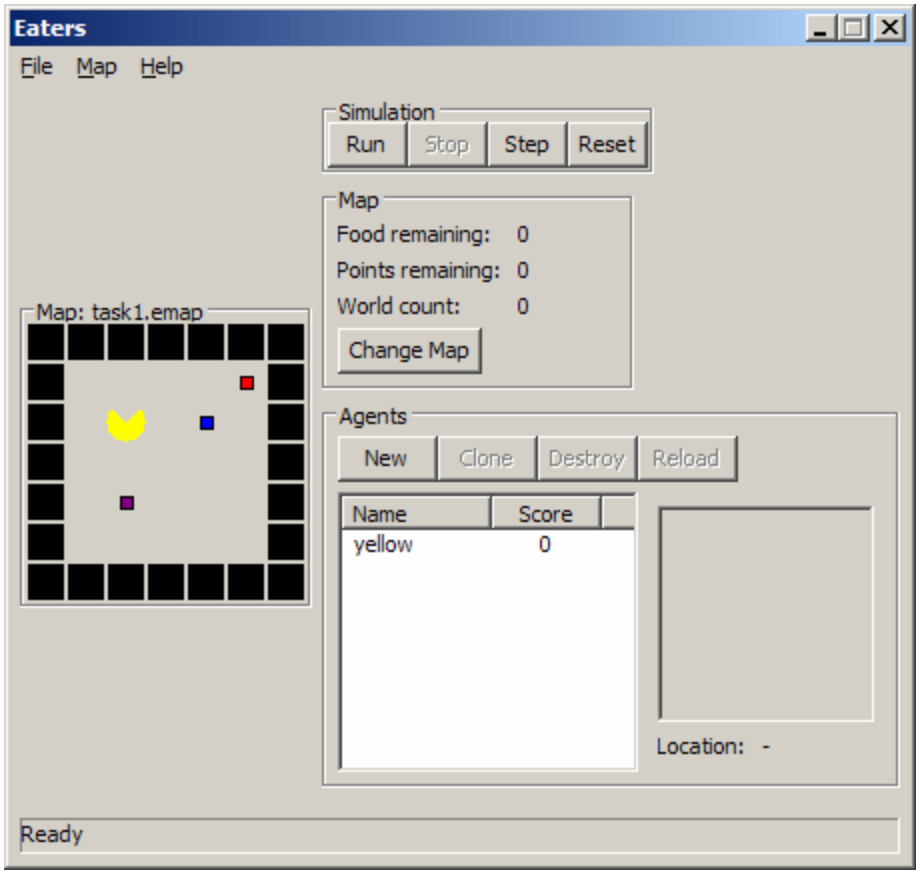
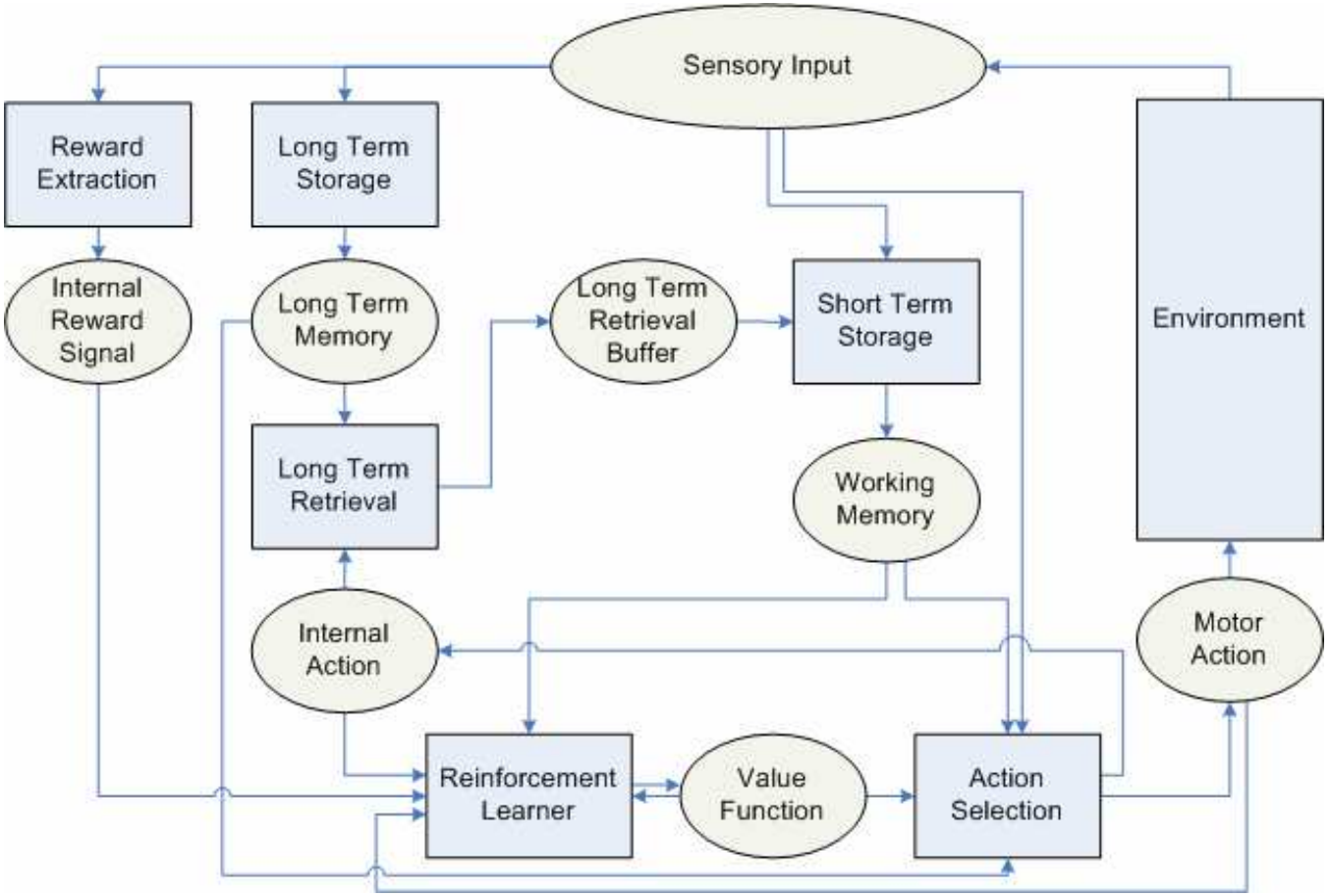


Initial Architecture in Storm



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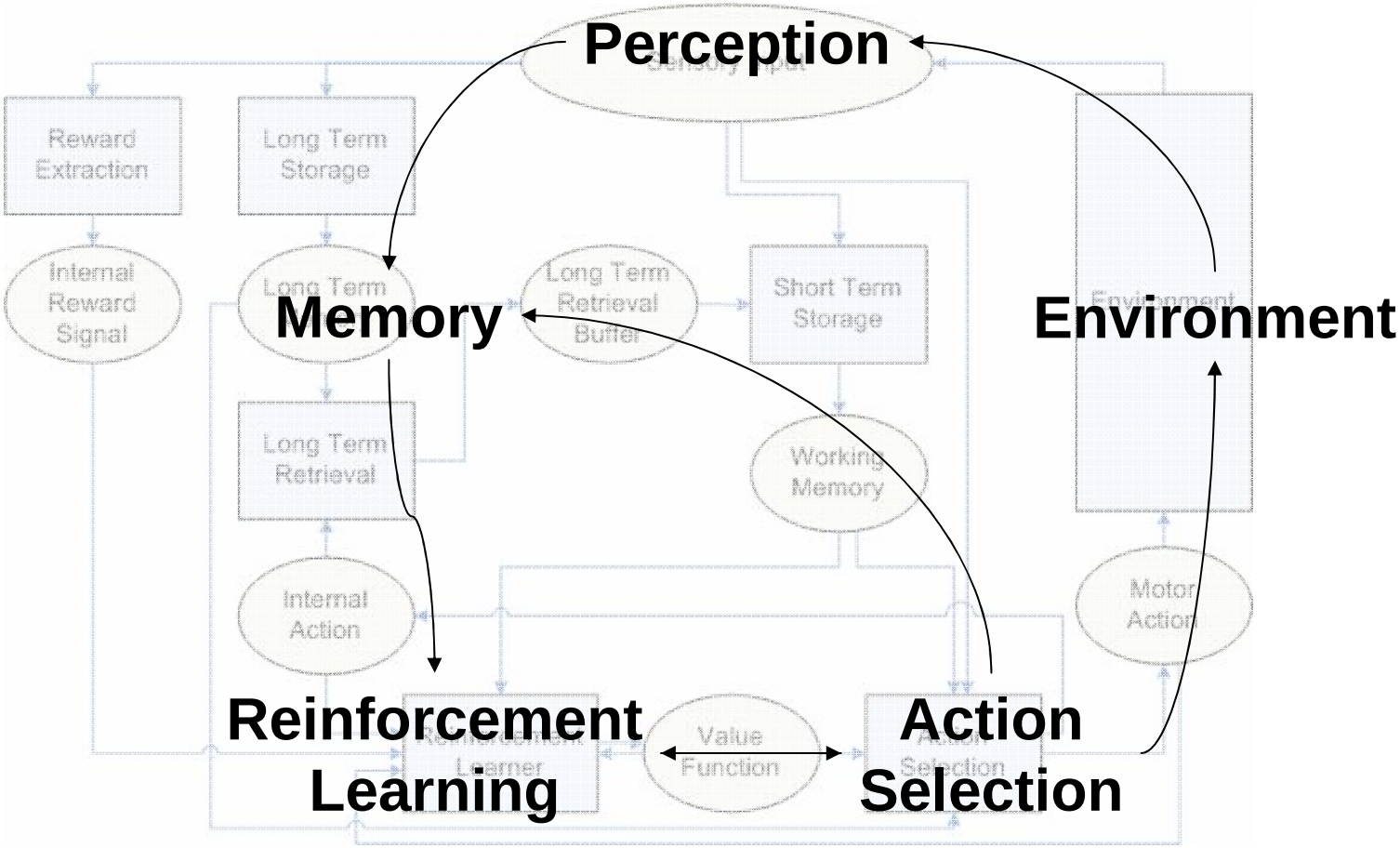

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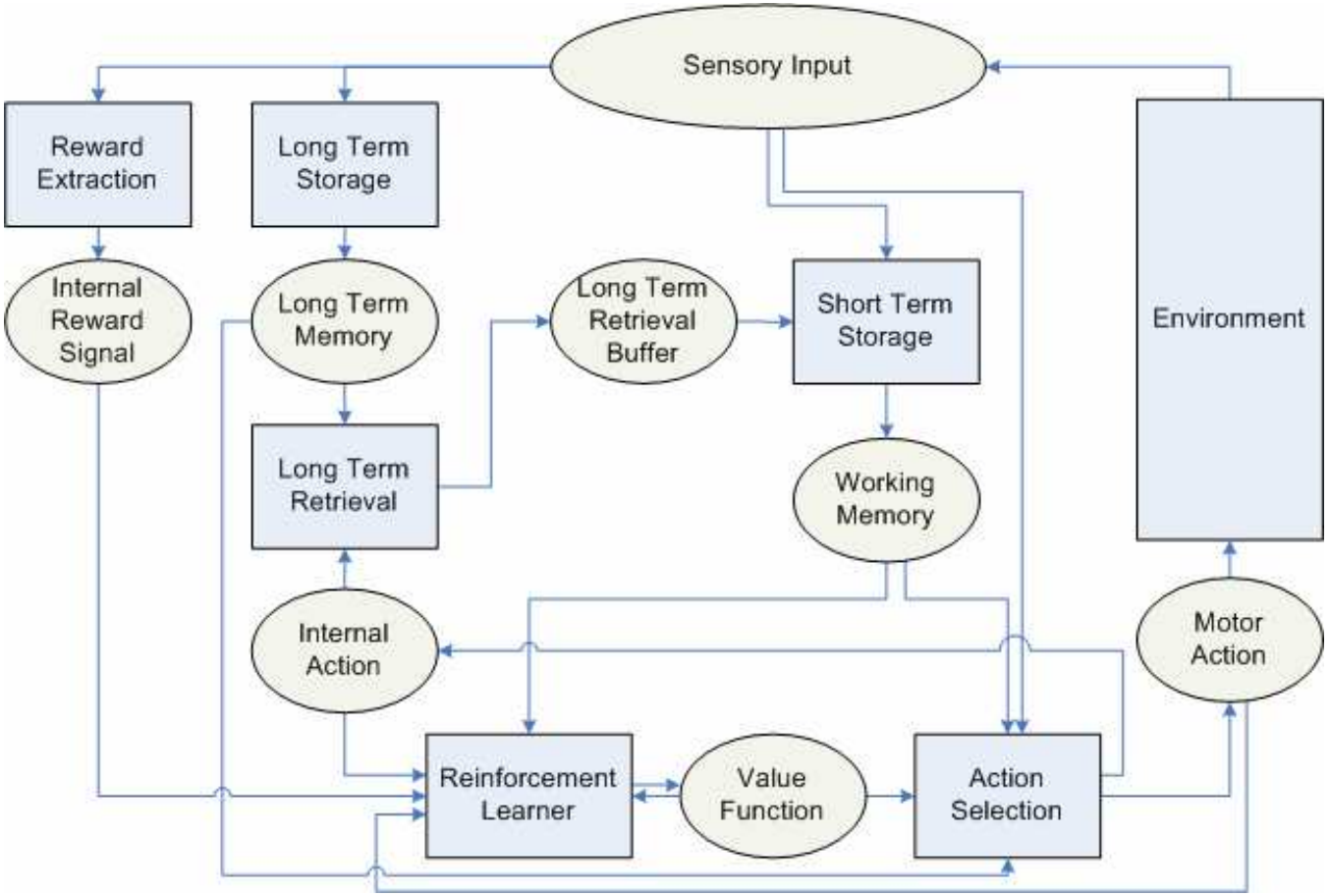
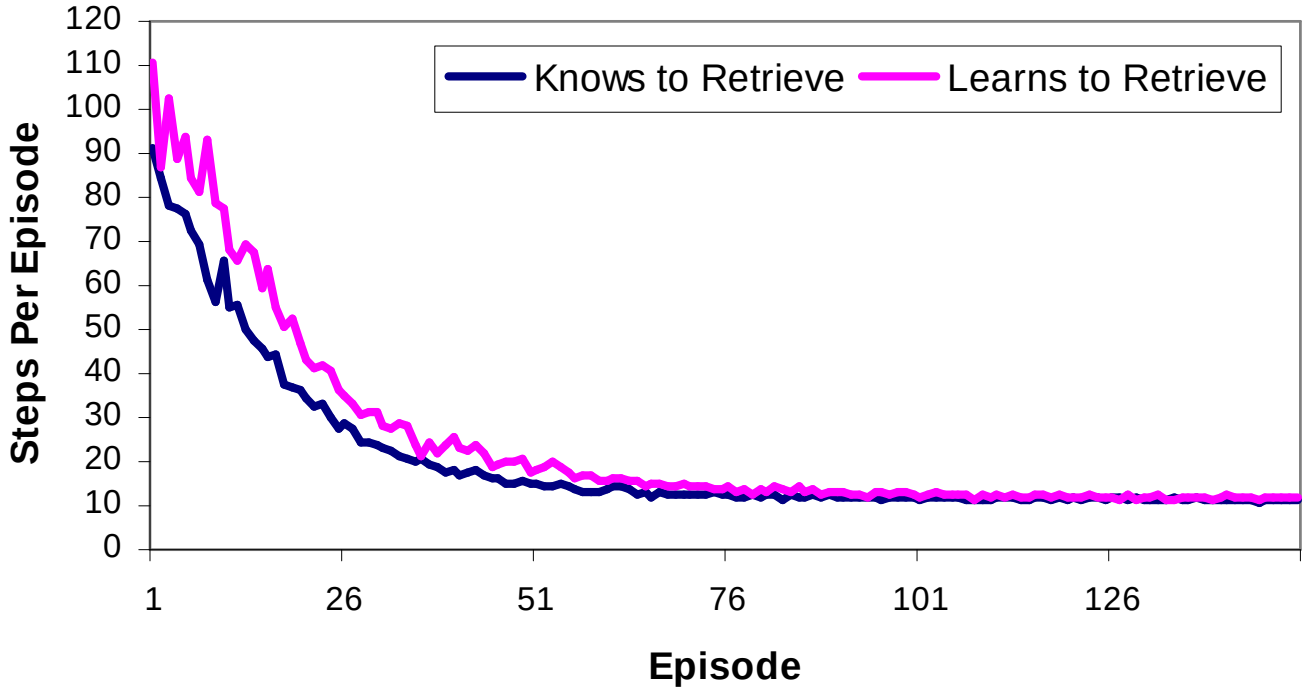


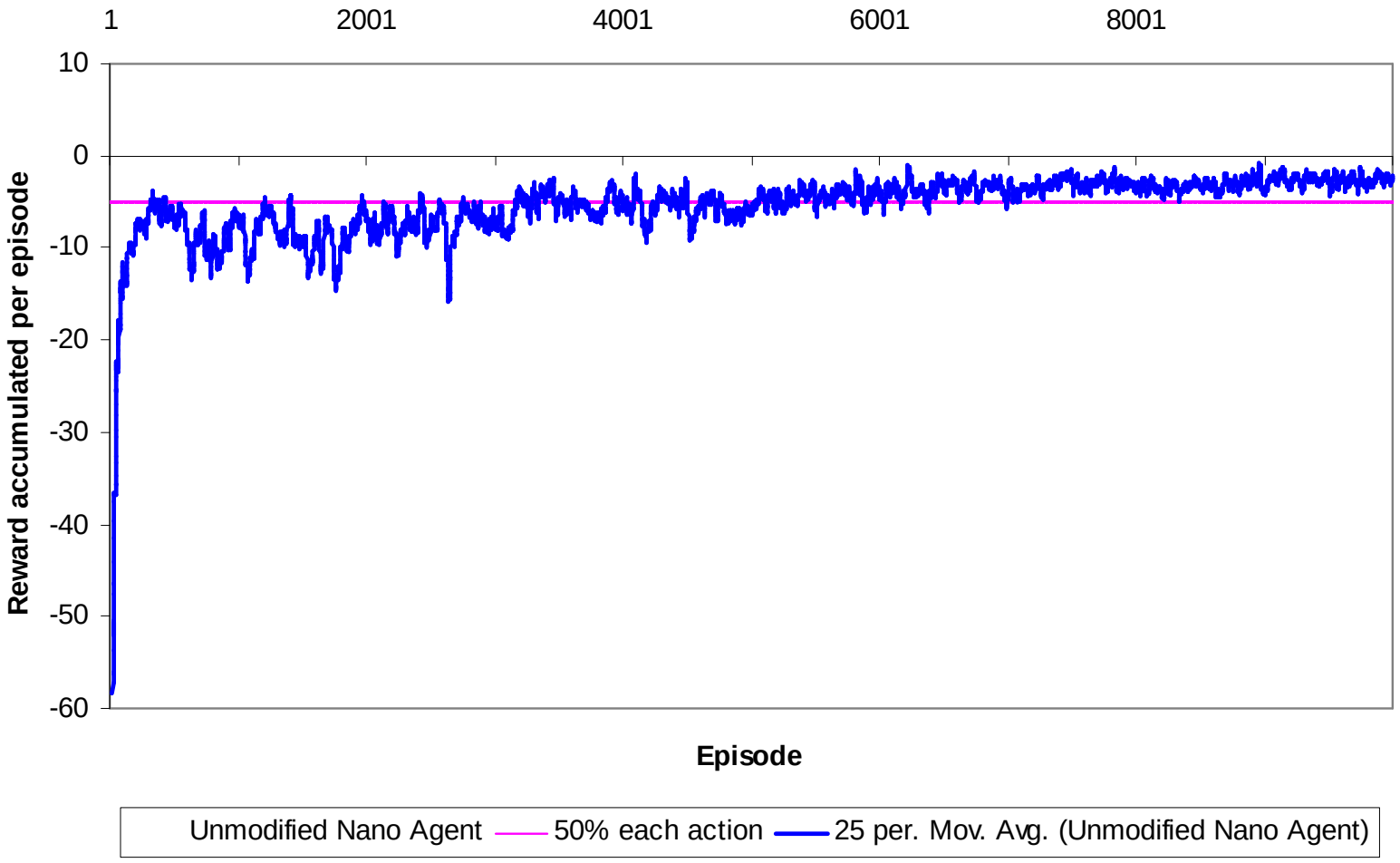
Task #1 – Results



Task #2 – SMT with Tools

- Message box contains two symbols
  - Identity of correct box
  - Identity of the correct action used to open box
- Rewards remain the same
  - Except that opening right box with wrong action results in +1 reward
- Requires learning when & what to retrieve

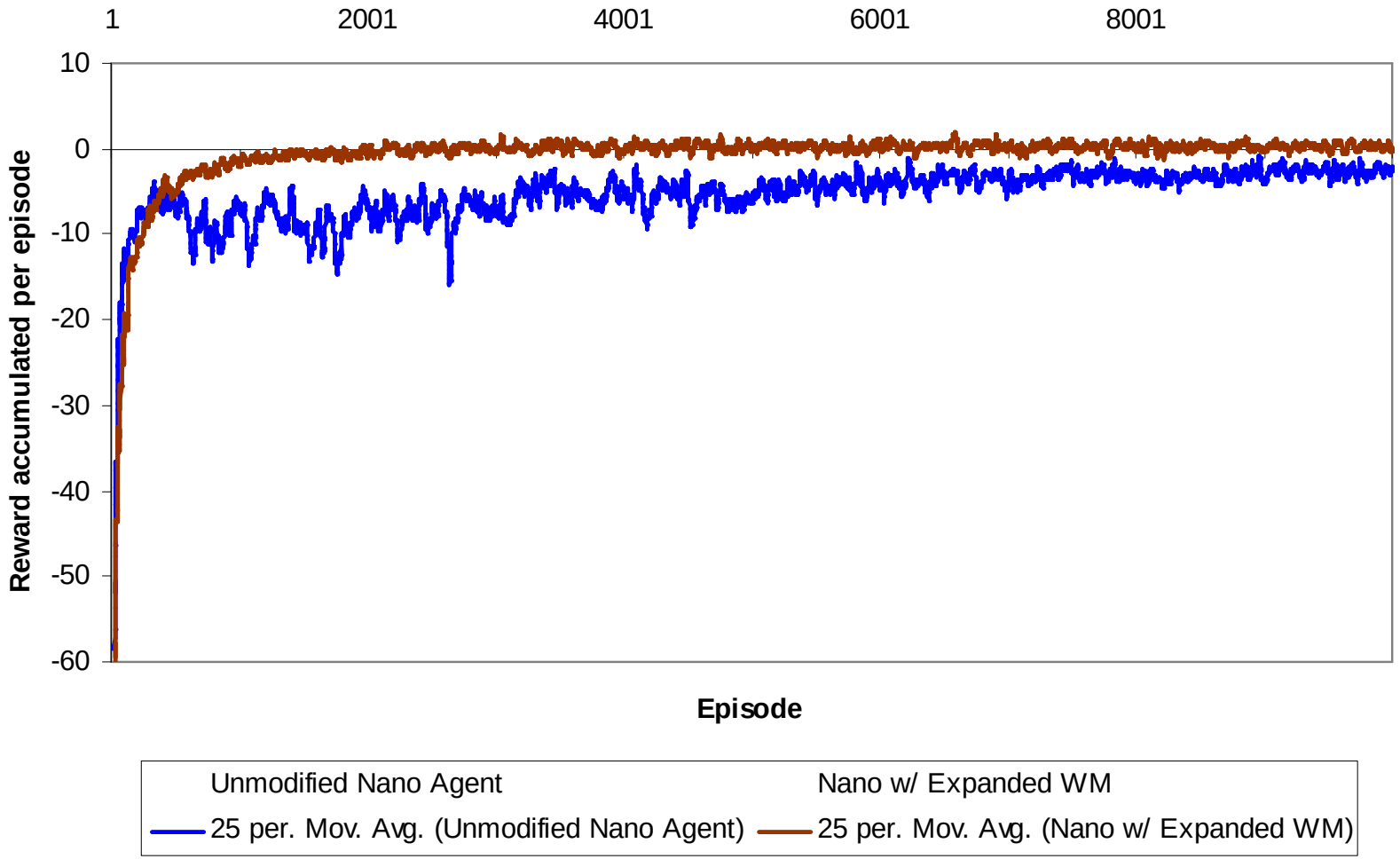
Task #2 – Results



Task #2 – Expand WM

- Storing only one symbol results in slow learning
  - Could expand working memory
  - Could use *sequences*
- State representation
  - Was <x, y, most recent symbol>
  - Now <x, y, most recent symbol, 2nd most recent symbol>
- How does expanding WM improve learning in Task #2?

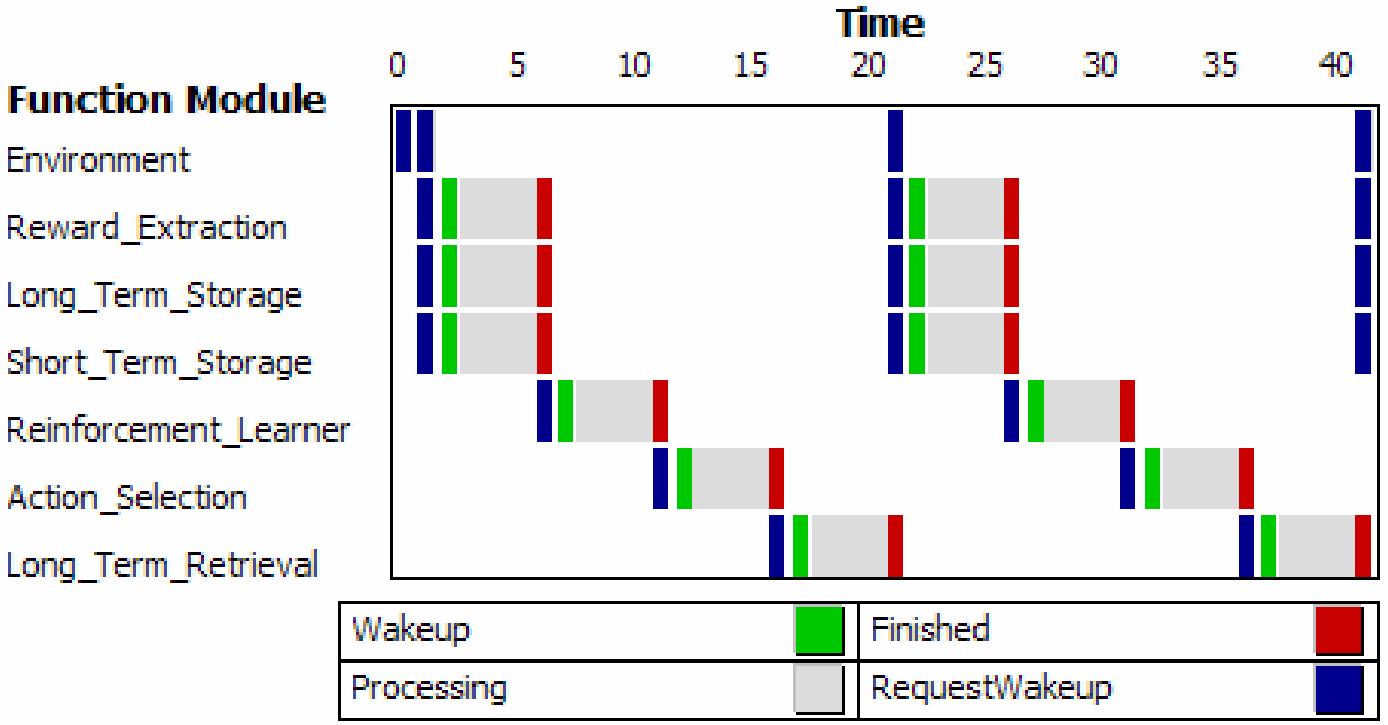
Task #2 – Results with Expanded WM



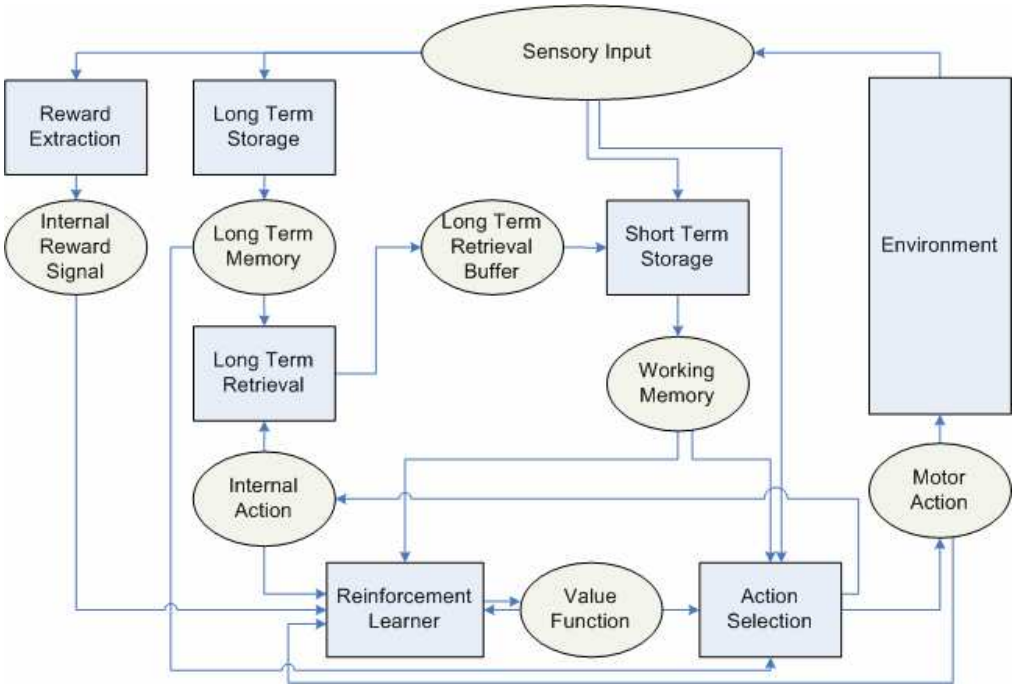
Task #2 – Delayed Retrieval

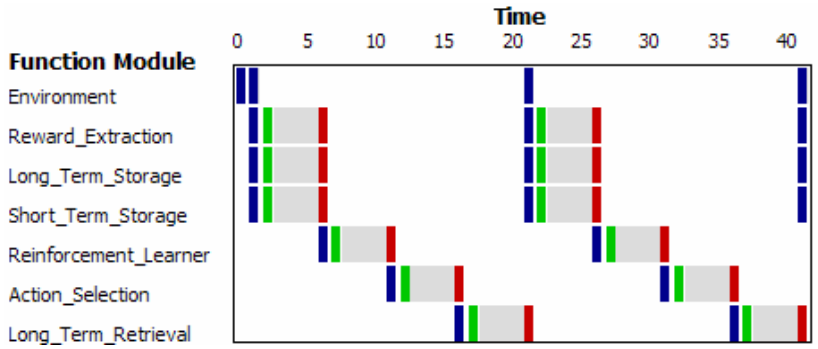
- Different function modules will eventually have different timing constraints
- Modification:
  - Was: LTM retrieval took 1 step in environment
  - Now: LTM retrieval takes 2 steps in environment
- Is a simple learning mechanism sufficient to learn with decoupled function modules?

Task #1 – Timing Trace

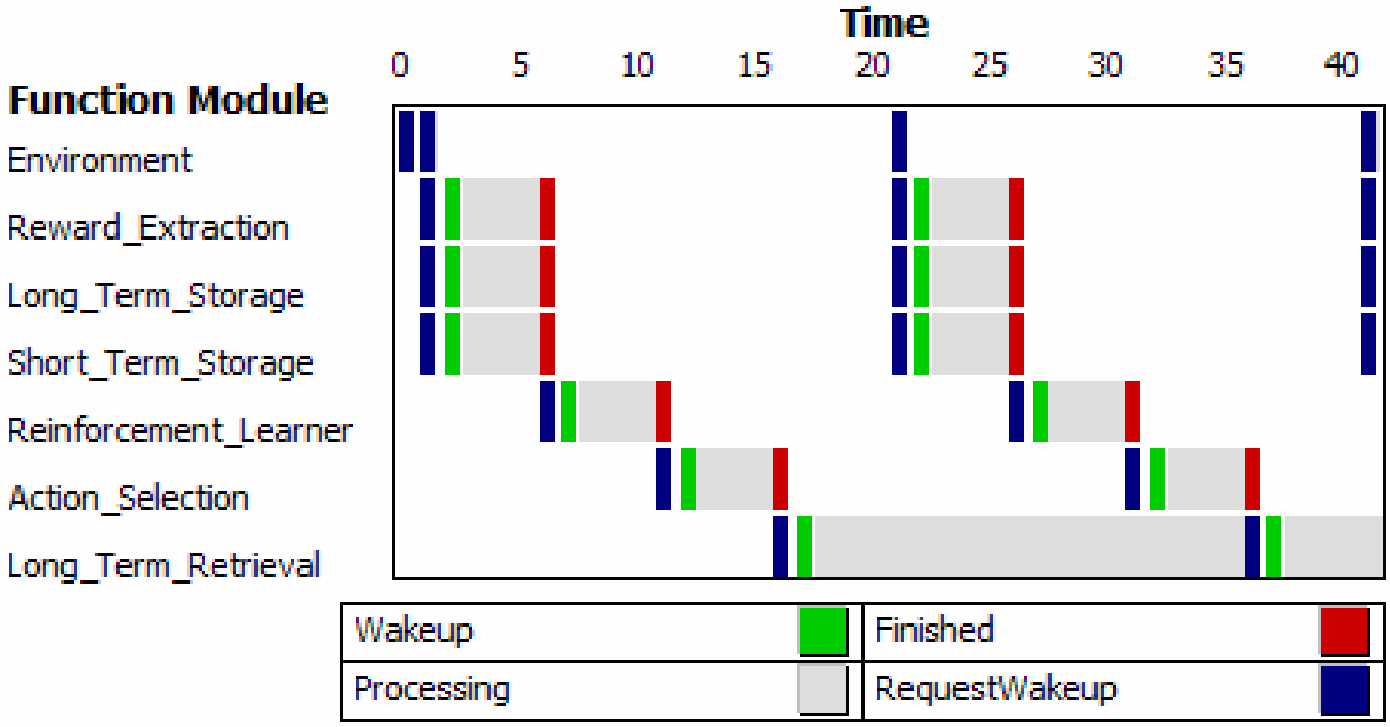


Timing in Initial Architecture





Delayed Long-term Retrieval



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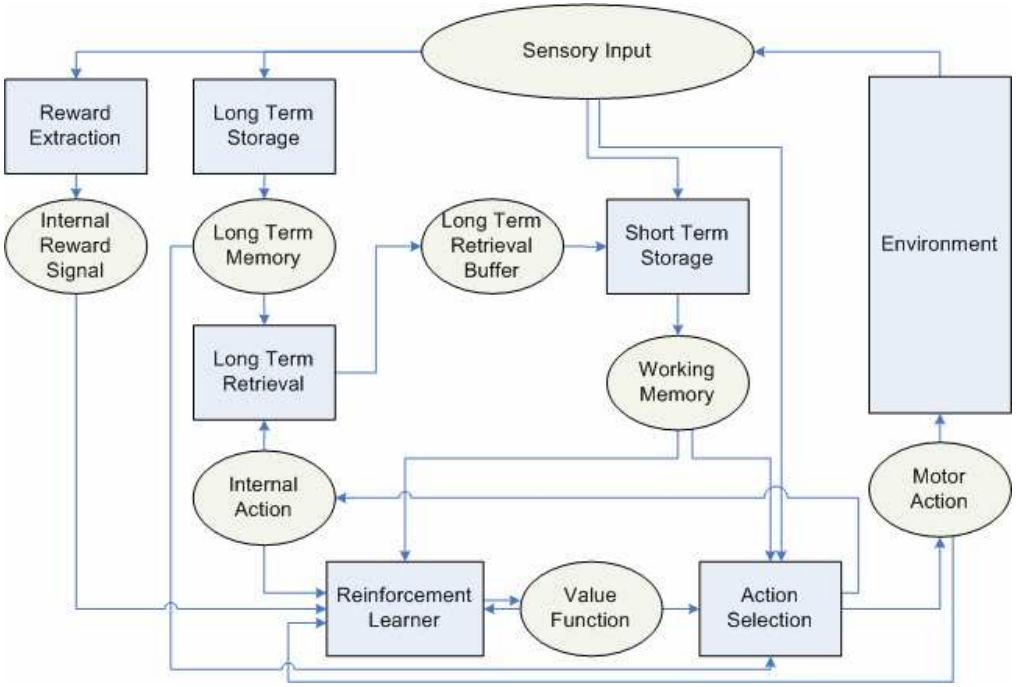

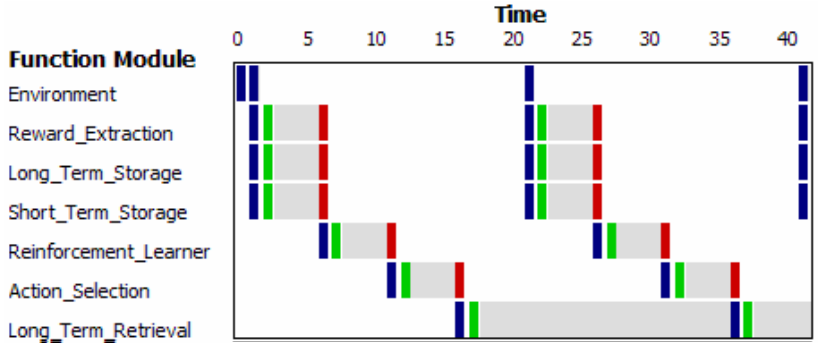

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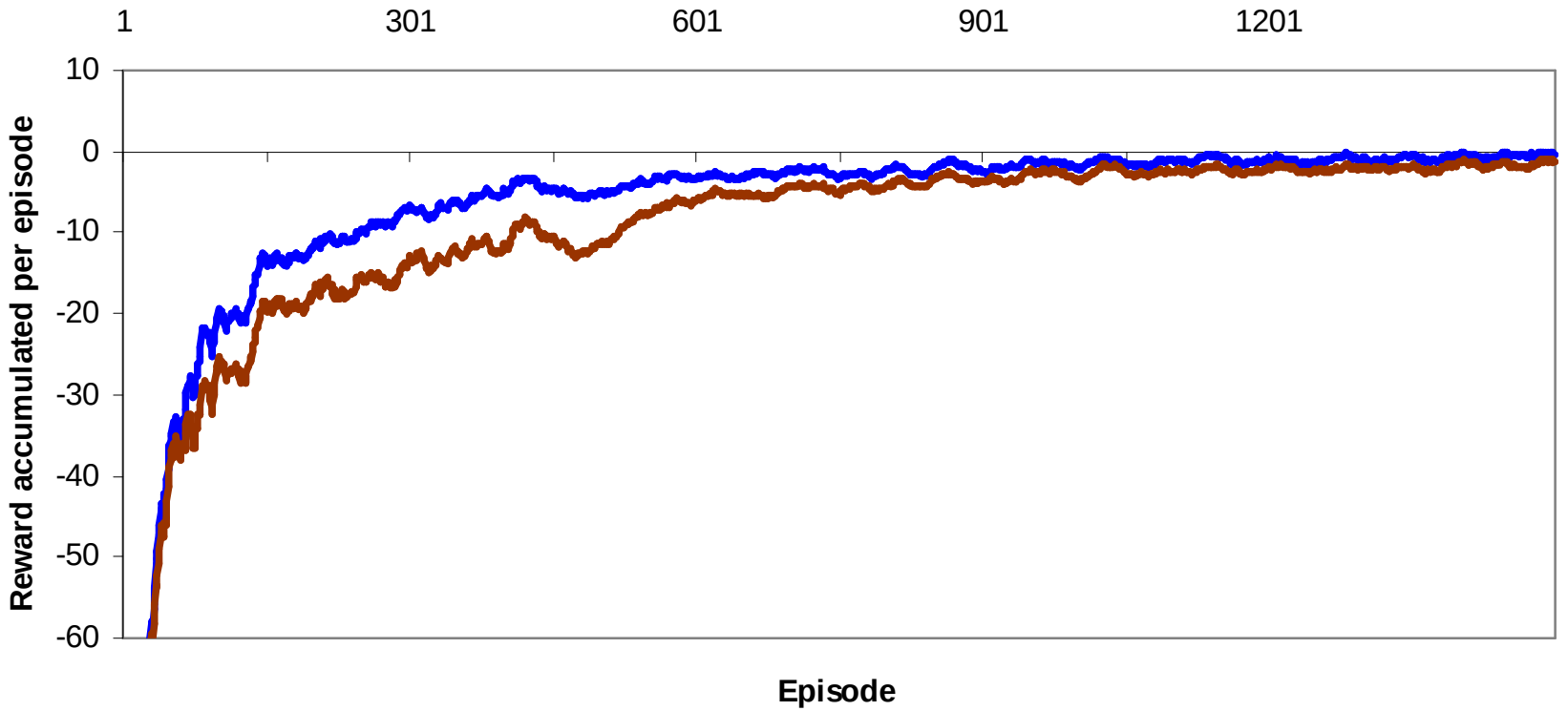

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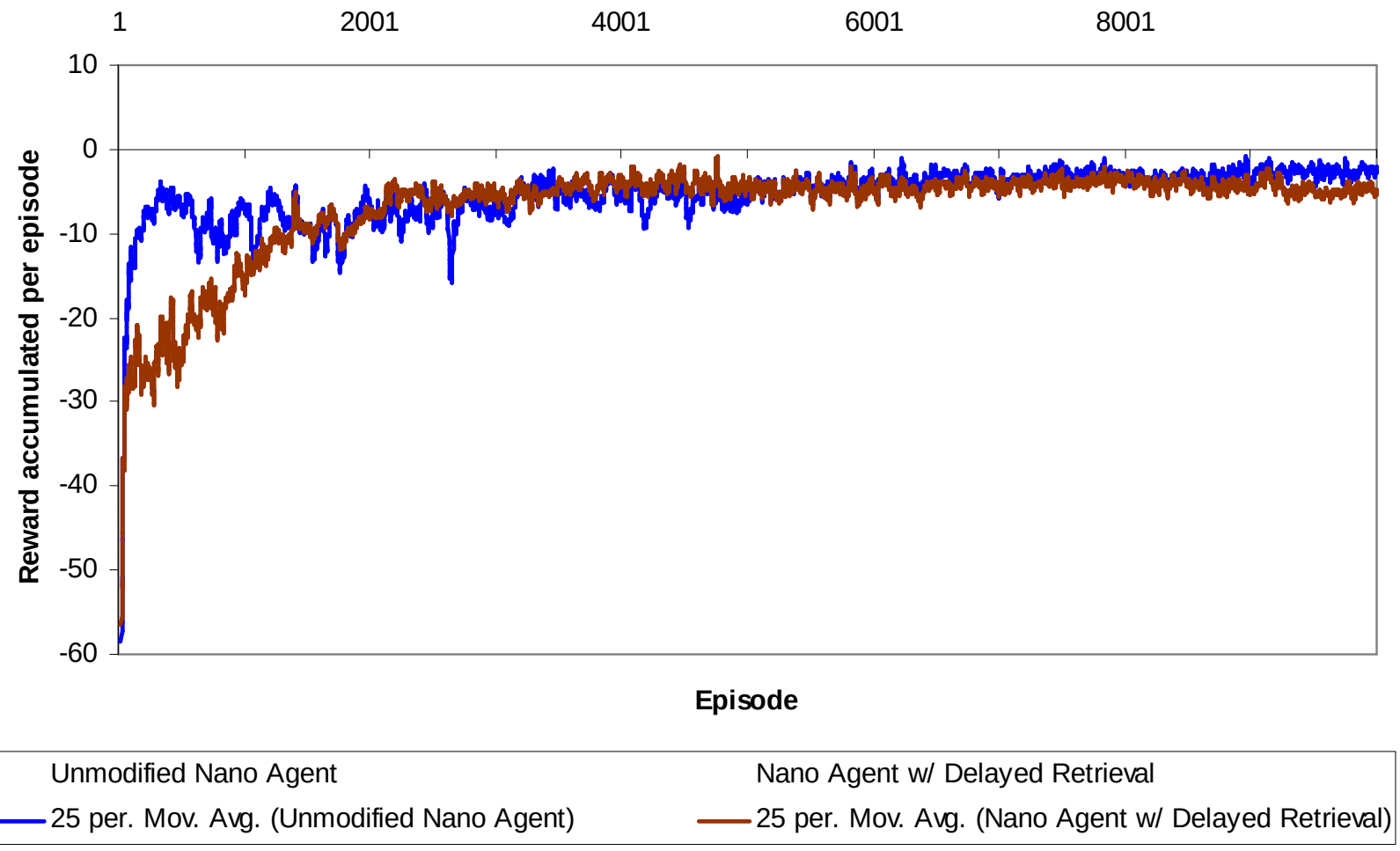

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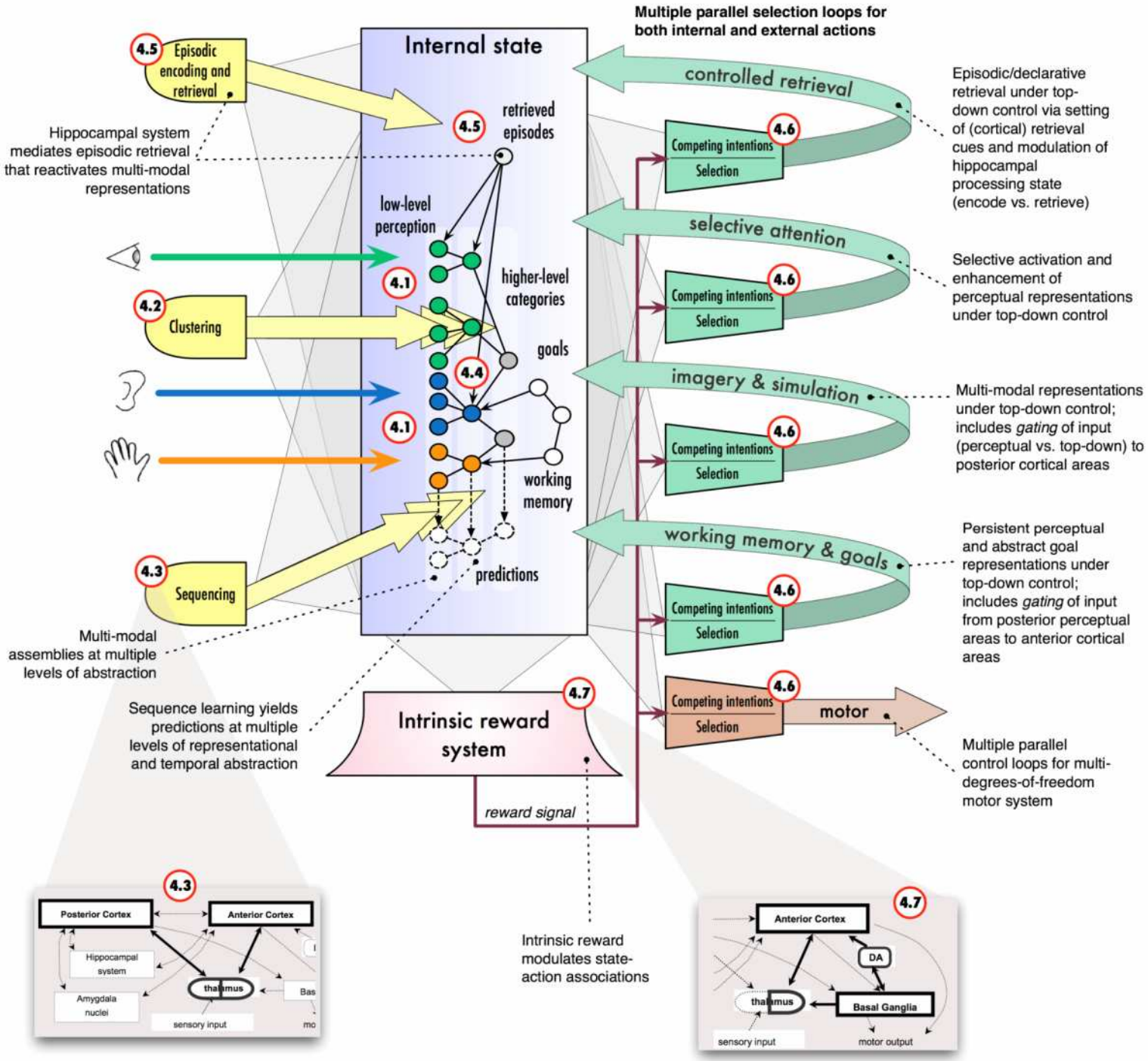
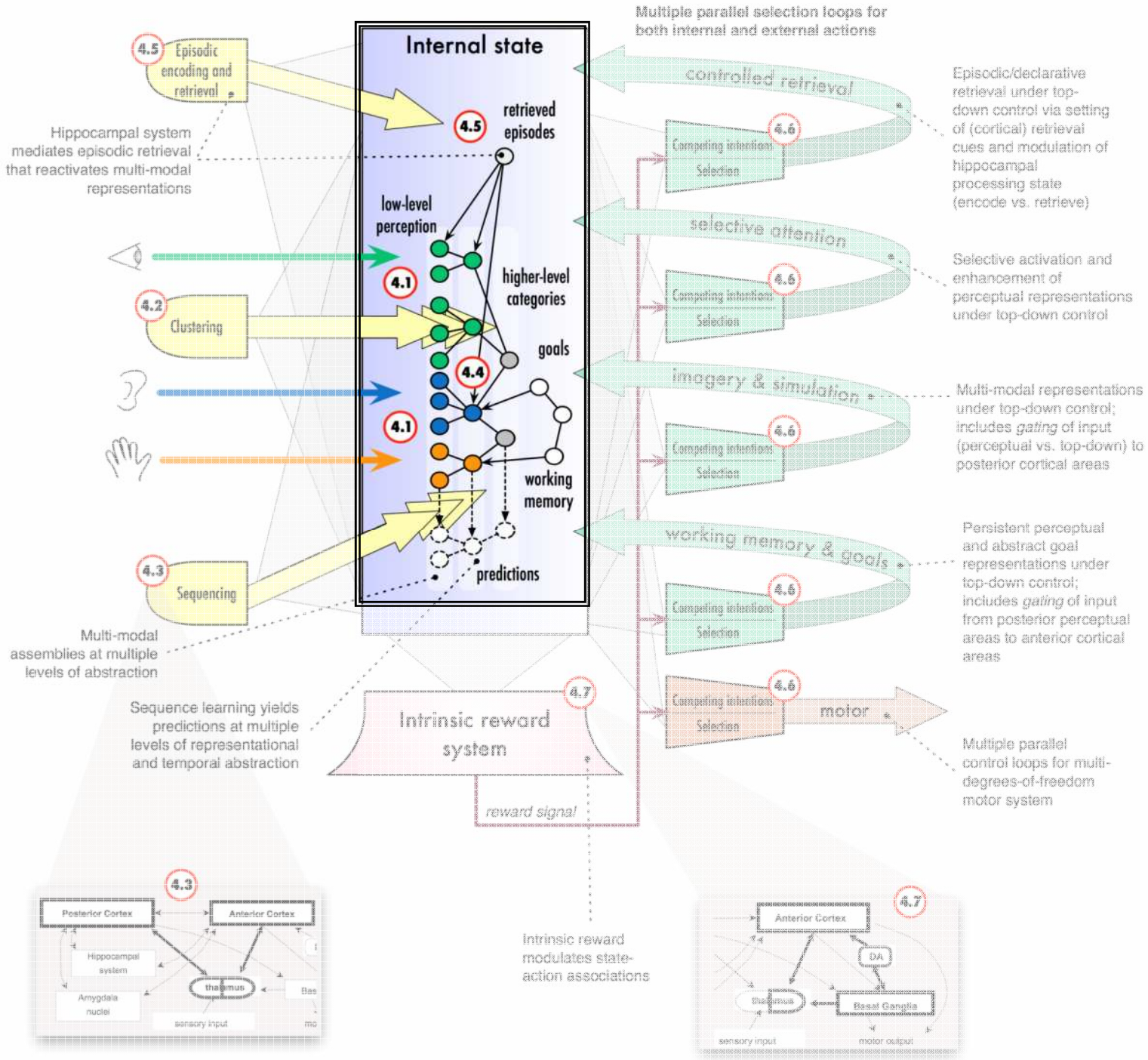
TOSCA Architecture

- Comprehensive design for an artificial mind, grounded in our knowledge of the brain
- Assumptions:
  - Brain as control system, no central controller
  - Asynchronous, parallel, distributed processing
  - Multiple internal memories
  - Continuous learning

http://www.darpa.mil/IPTO/Programs/bica/TOSCA_Architecture.pdf

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retrieved episodes
low-level perception
higher-level categories
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4.2 Clustering
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Multi-modal assemblies at multiple levels of abstraction
Sequence learning yields predictions at multiple levels of representational and temporal abstraction
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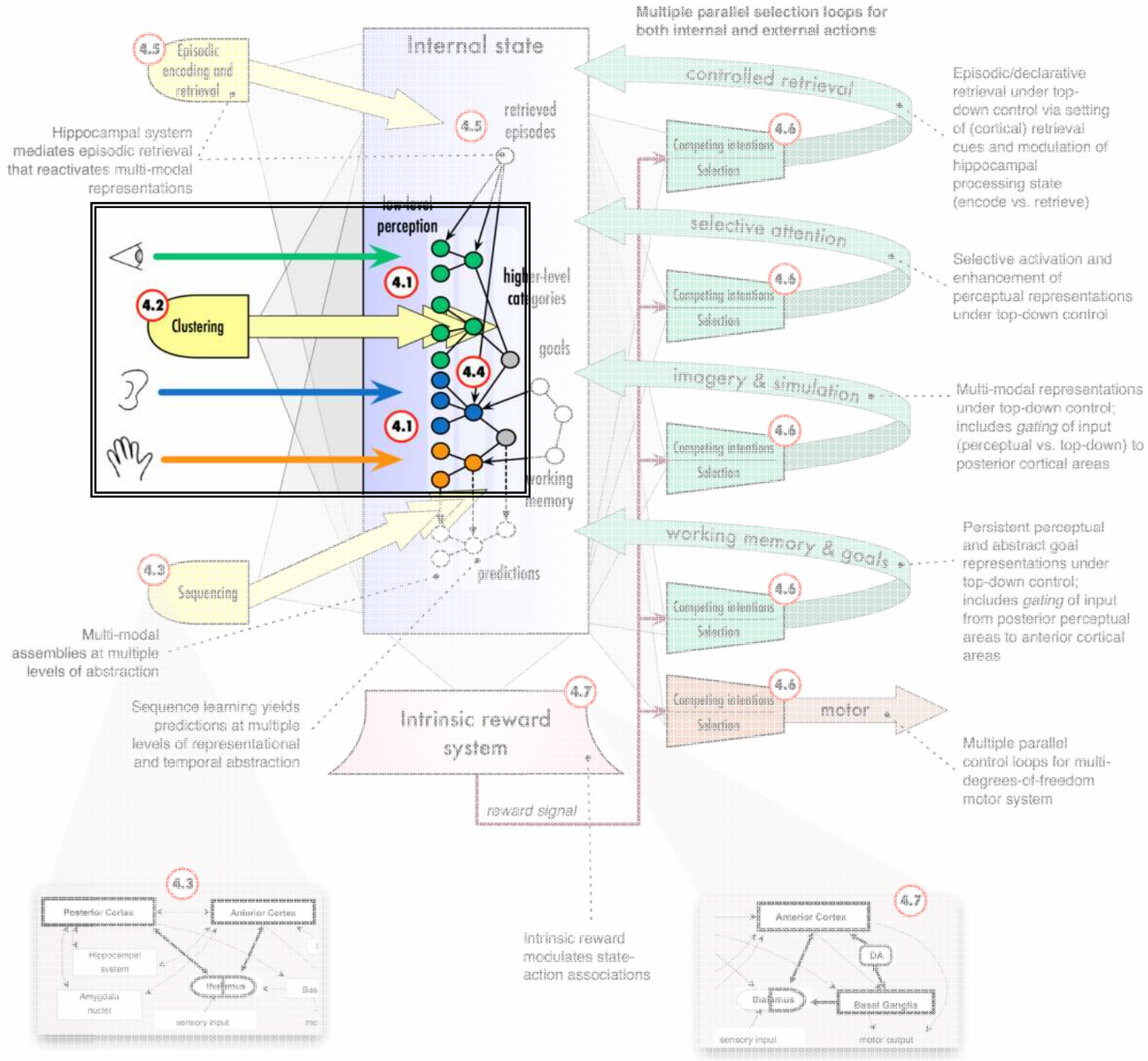
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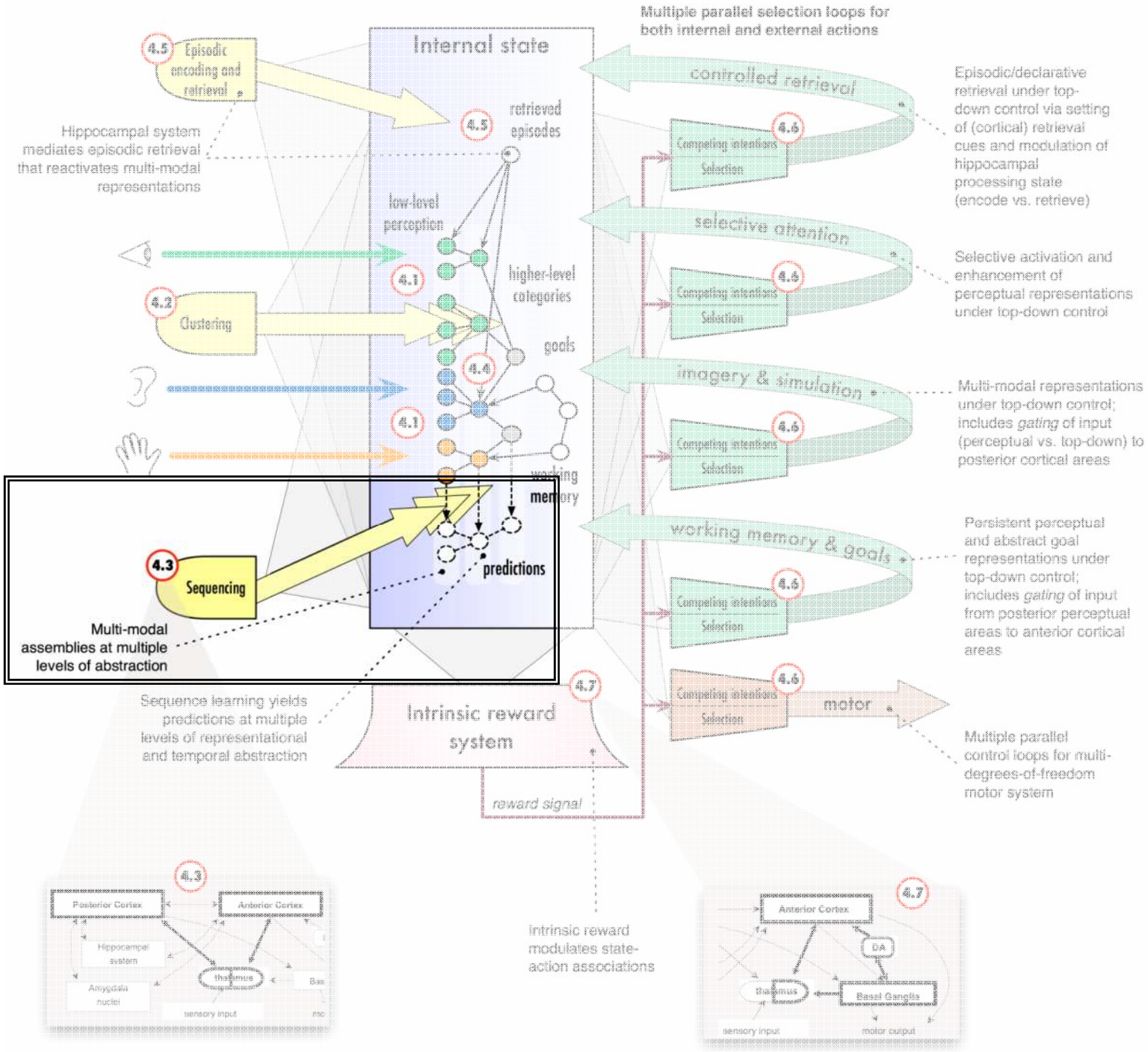
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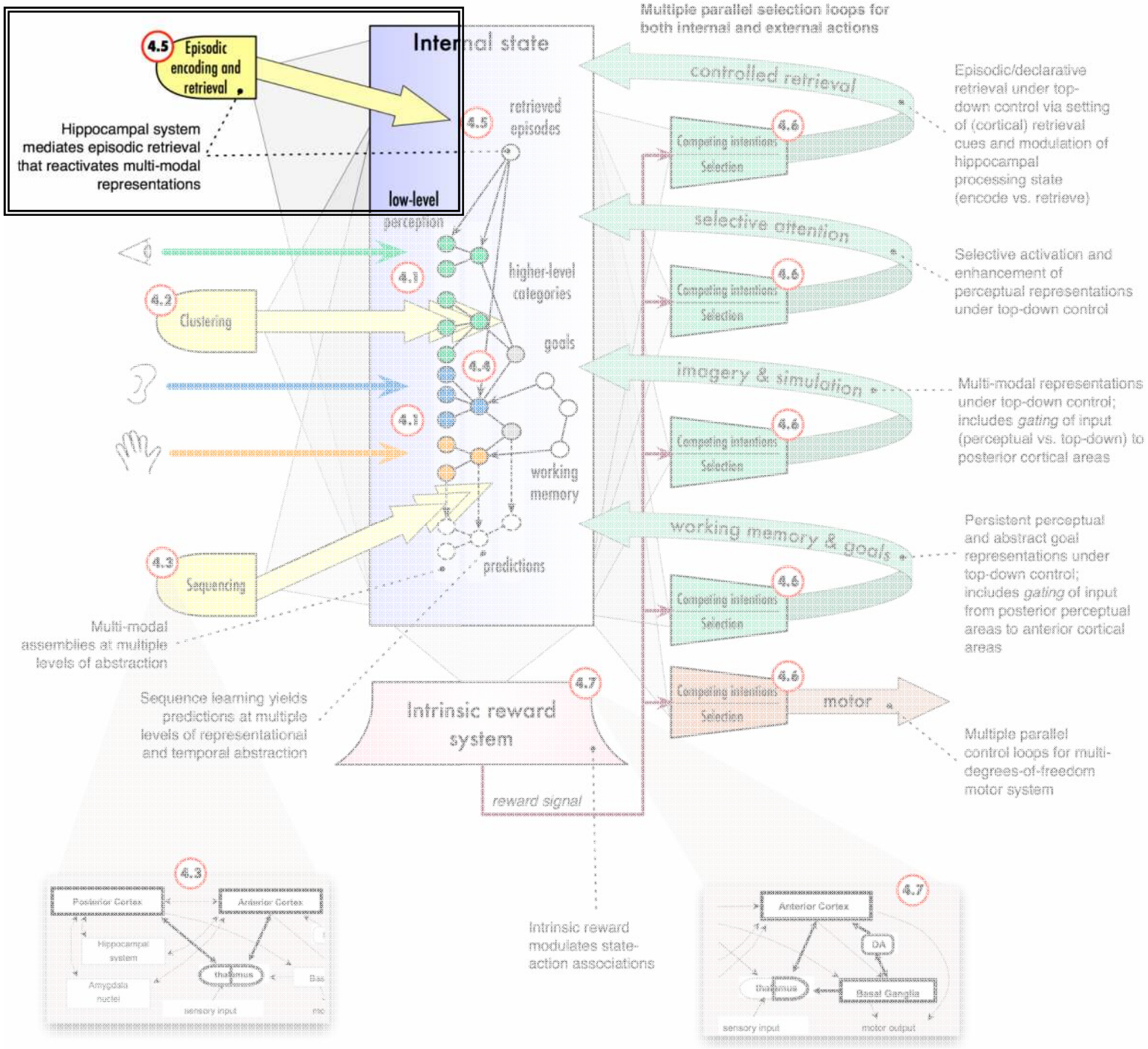
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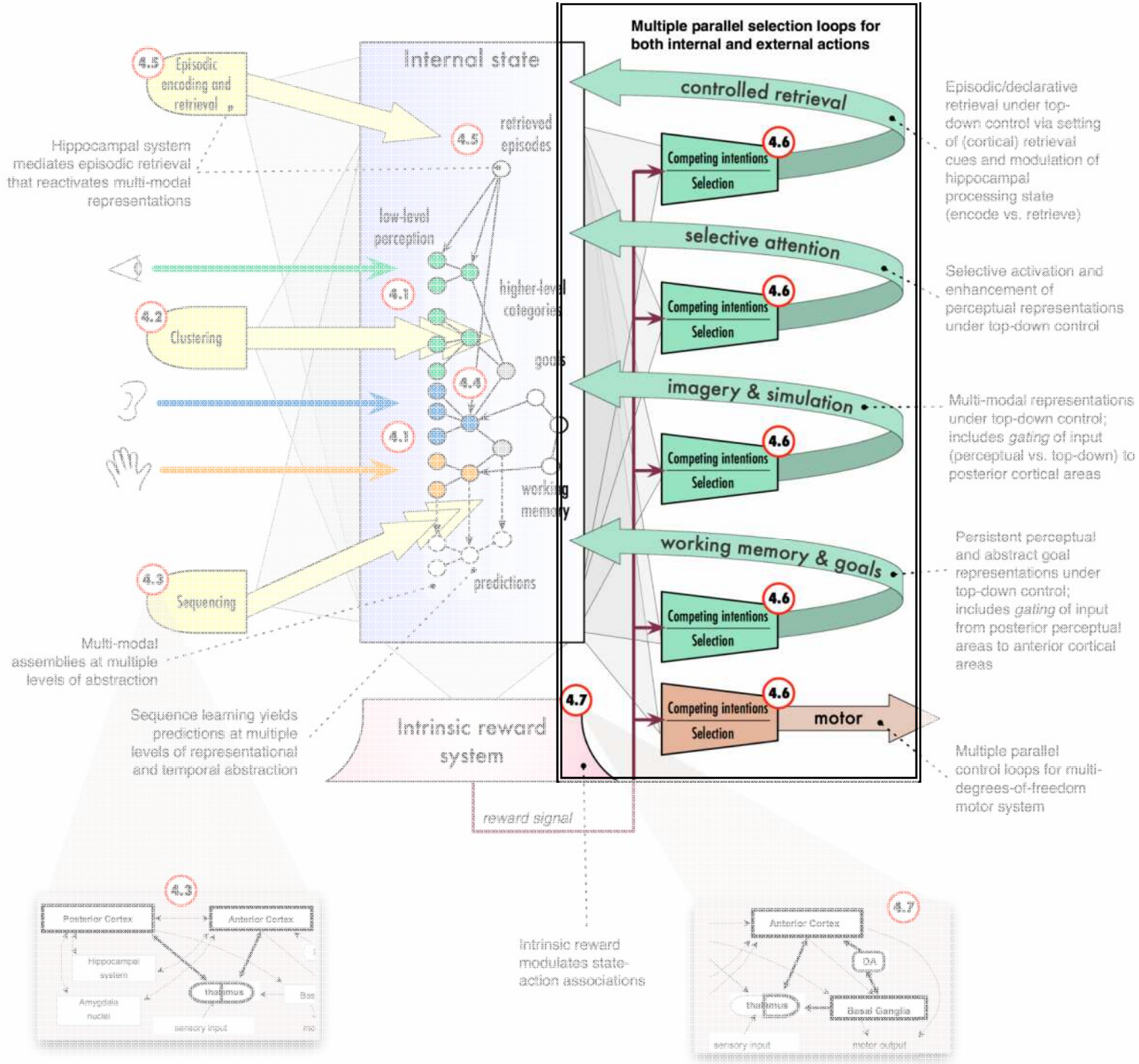
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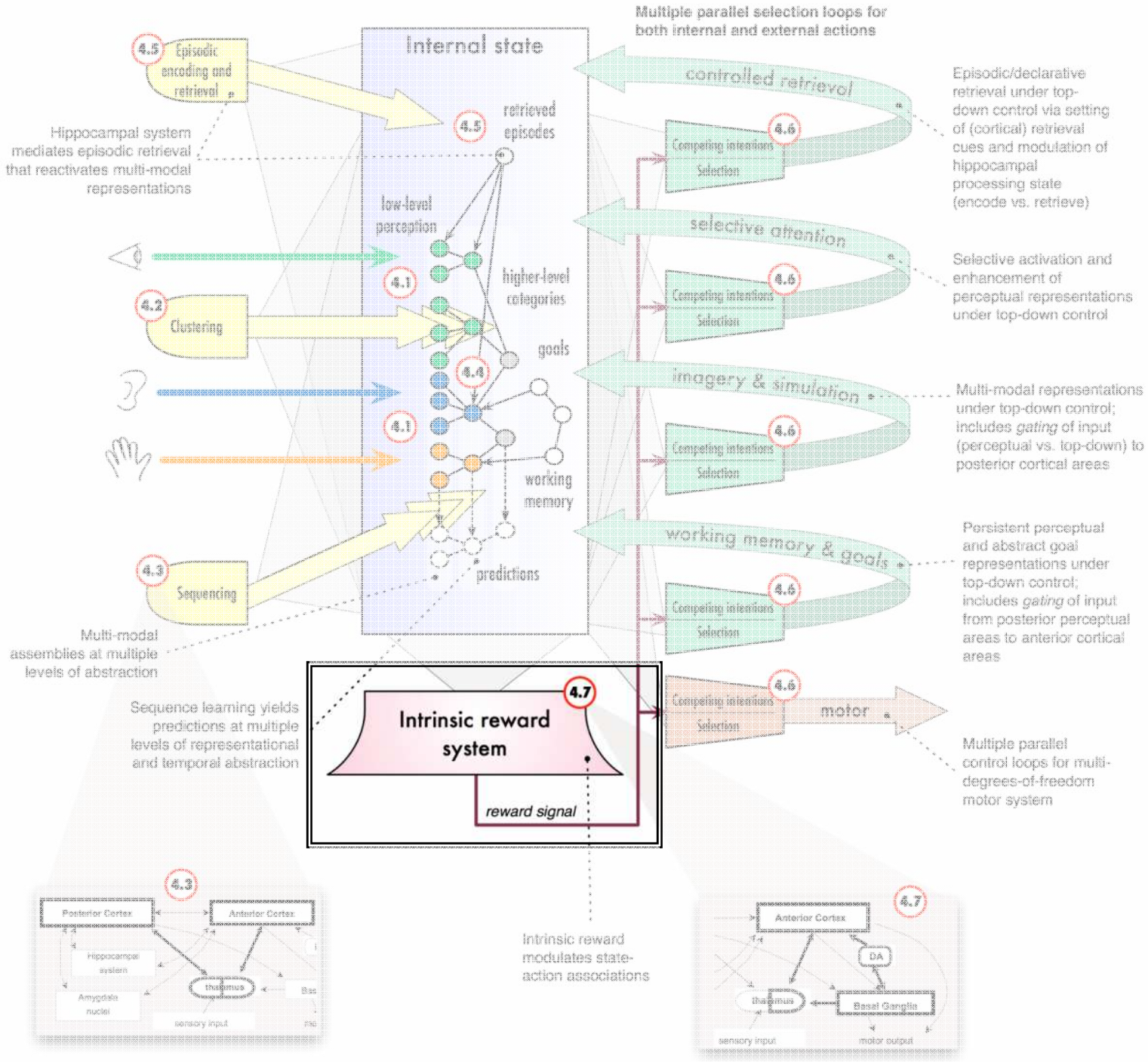
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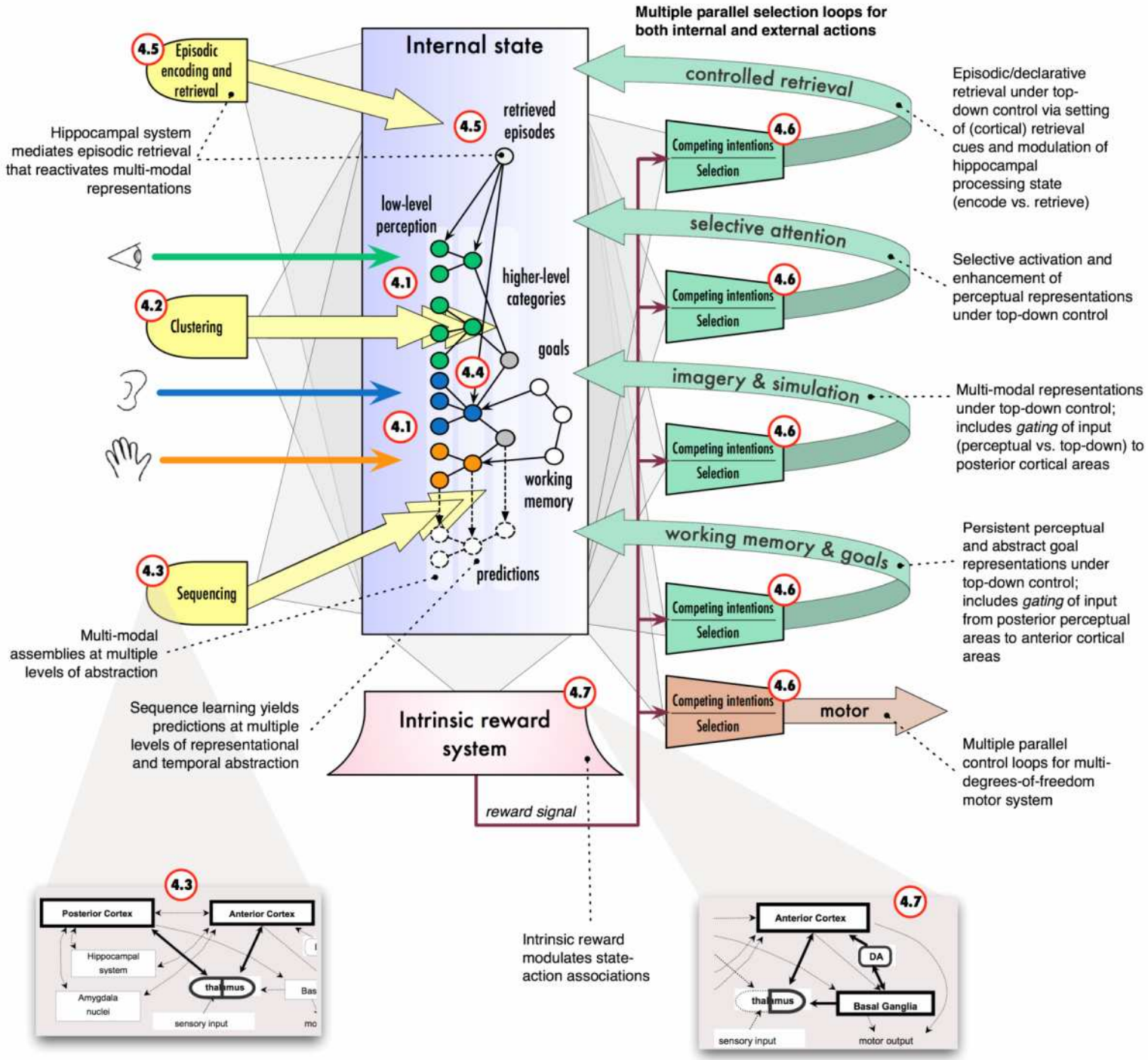
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Comparisons with Soar-like CAs

- Core data structure:
  - Symbol structures
  - Defined by programmer
- Programmable
  - Human understandable
  - Directly taskable
- Real time using conventional computational hardware

- Core data structure:
  - Numeric vectors
  - Symbol emerge?
  - Based on sensory modalities?
- Trainable
  - Almost everything is learned
  - Motivated by internal drives
- Not close to real time today, requires massive parallel computation

Gold Nuggets & Lumps of Coal

- Actively Using framework
- Accomplishing ST Goals
  - Debug/test framework
  - Explore architectural commitments
  - Iteratively develop complex architectures

- Simple architecture
- Simple tasks
- Lots of work left to be done…
  - Both by researchers
  - AND by a learning architecture