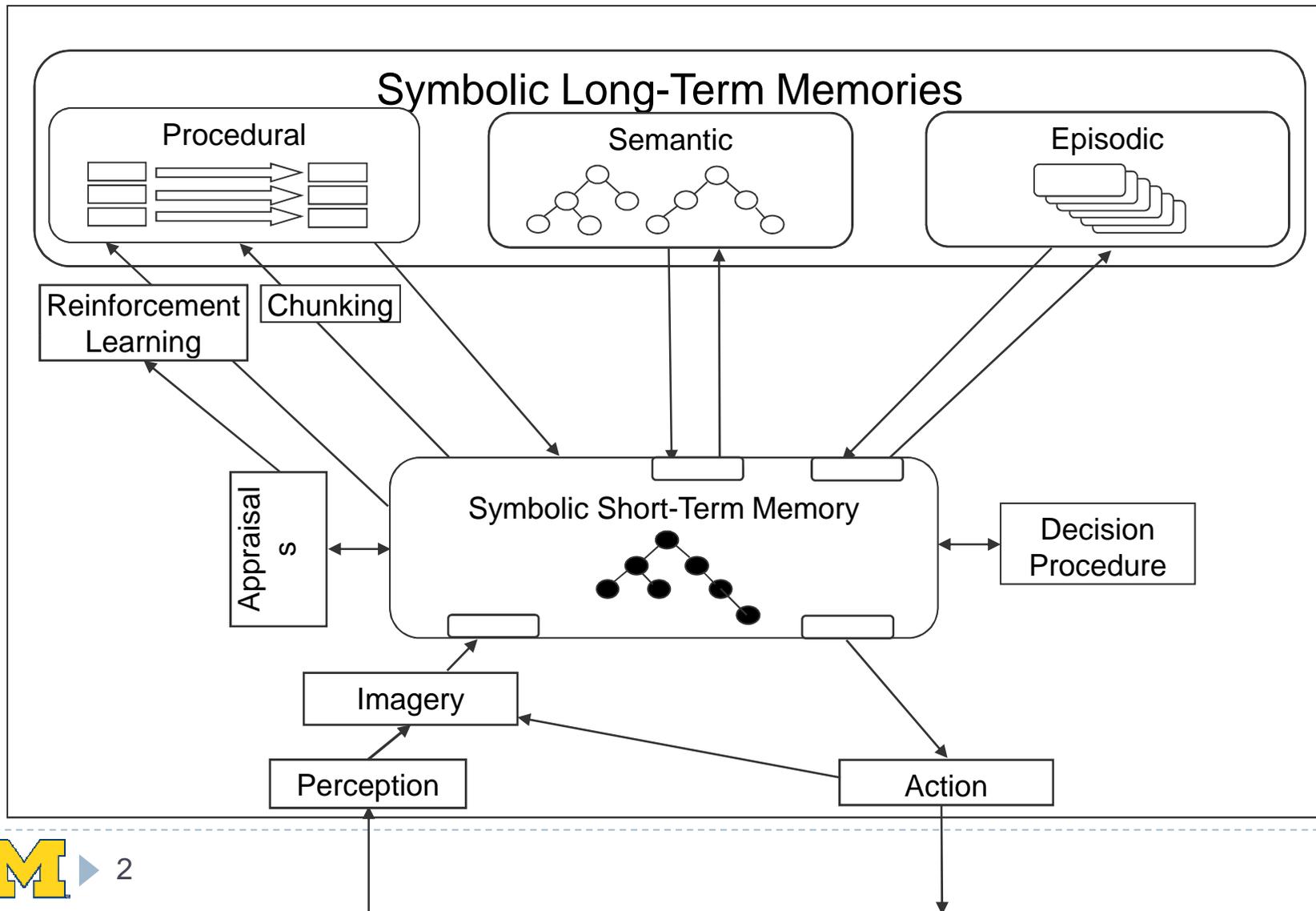


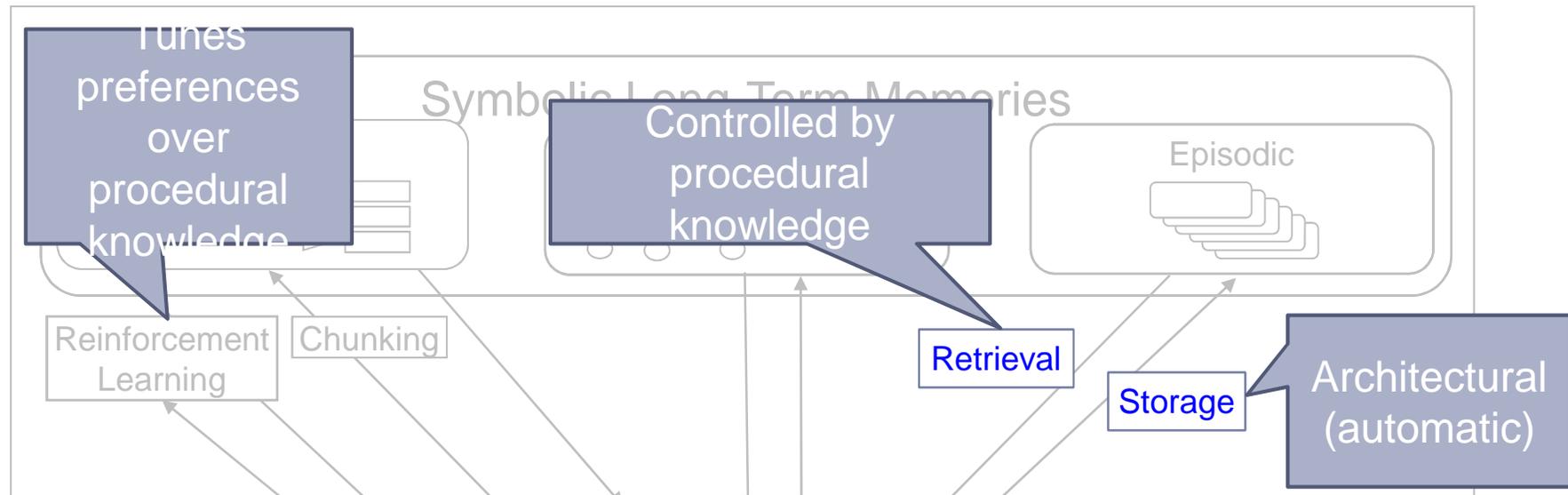
Learning to Use Episodic Memory

Nicholas Gorski
June 25, 2009

Learning to Use Episodic Memory



Learning to Use Episodic Memory



- ▶ **EpMem**
 - ▶ requires procedural knowledge to guide behavior
- ▶ **RL**
 - ▶ has difficulty in tasks that require history
- ▶ **Integration of RL & EpMem**
 - ▶ Potential source of control knowledge for EpMem retrievals
 - ▶ Potential source of history knowledge for RL decision making

Learning to Use Episodic Memory

▶ Primary research questions:

1. Can an agent learn to use EpMem while doing a task?
2. What are the issues that arise when an agent learns to use memory?



“Using” Episodic Memory

- ▶ Using EpMem means making retrievals
 - ▶ When to make a retrieval
 - ▶ Which cue to use
 - ▶ Selecting a cue from a set of available cues
 - ▶ Building a cue from primitive features
 - ▶ When to advance to the next memory (temporal control)

Introducing Well World

- ▶ **Simple...**
 - ▶ Only several objects in the world (3-4)
 - ▶ Only several possible actions
- ▶ **...Yet Challenging**
 - ▶ Partially observable: memory-less agent can't observe complete state of the system



Well World: A Simple Domain for Learning to Use Episodic Memory

Situation: Agent **is** thirsty and at well that contains water



Behavior: Agent drinks water and is rewarded

Well #1 becomes empty and well #2 becomes full

Well World: A Simple Domain for Learning to Use Episodic Memory

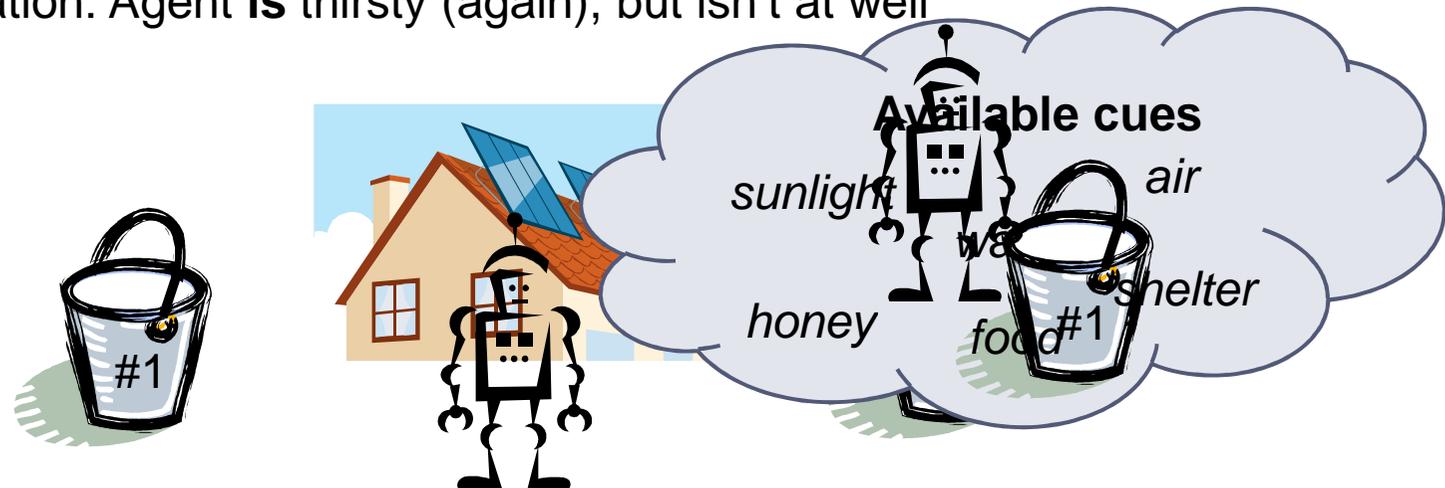
Situation: Agent **is not** thirsty



Behavior: Agent moves to shelter, rests, and is rewarded

Well World: A Simple Domain for Learning to Use Episodic Memory

Situation: Agent **is** thirsty (again), but isn't at well



Behavior: Agent selects a cue and performs a memory retrieval

Agent needs to learn to retrieve memory of when it last saw water (#1)

Well World: A Simple Domain for Learning to Use Episodic Memory

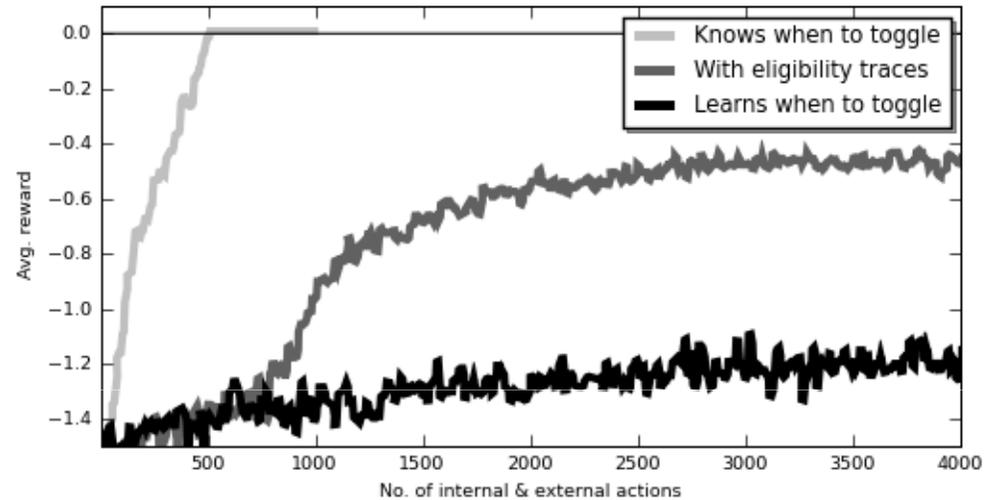
Situation: Agent **is** thirsty (again), but isn't at well



Behavior: Agent selects a cue and performs a memory retrieval

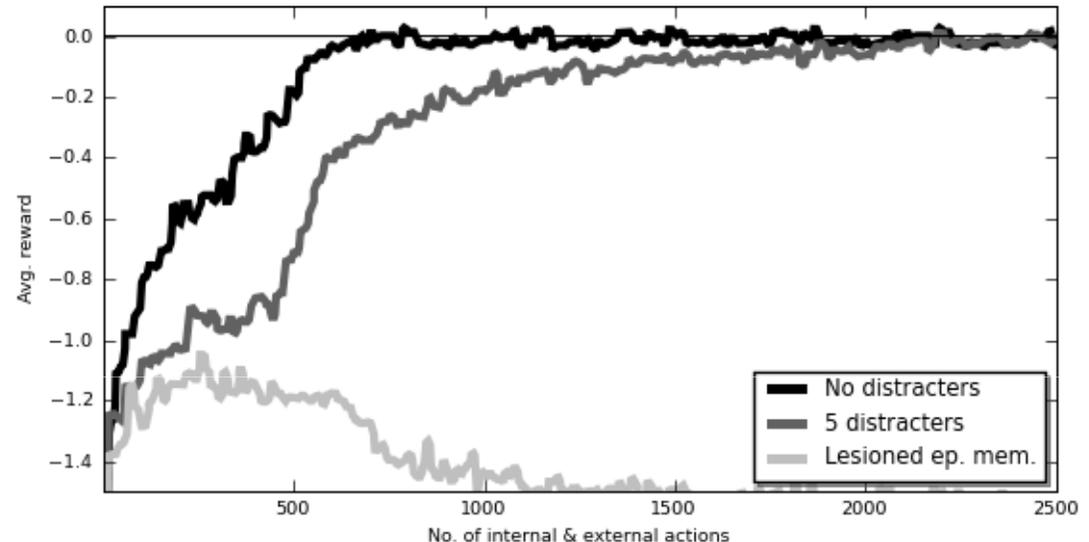
Agent needs to learn to retrieve memory of when it last saw water (#1) and learn to move to other well (#2), drink water there, and be rewarded

Learning to Use Bit Memory



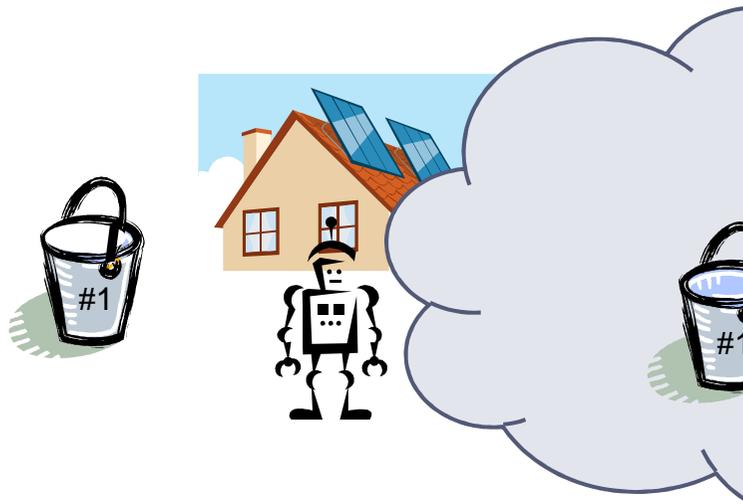
- ▶ Agent must learn
 - ▶ When to toggle bit to true
 - ▶ Bit automatically toggled to false after consuming Well_1
- ▶ Result: agent is unable to effectively learn to use bit memory

Learning to Retrieve Episodic Memories

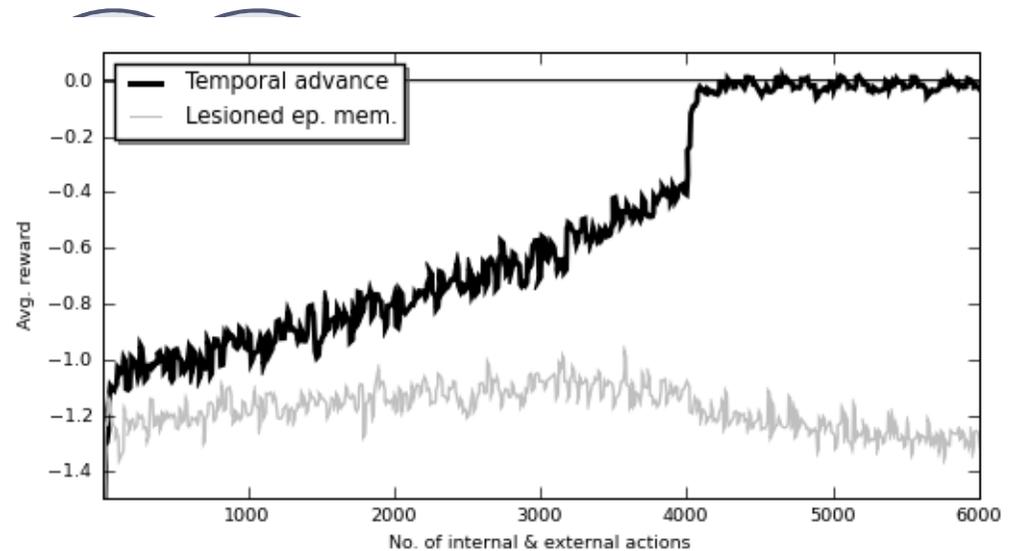


- ▶ Agent learns:
 - ▶ When to perform retrieval (when it gets thirsty)
 - ▶ Which cue to use for retrieval

Learning to Retrieve What Happened Next



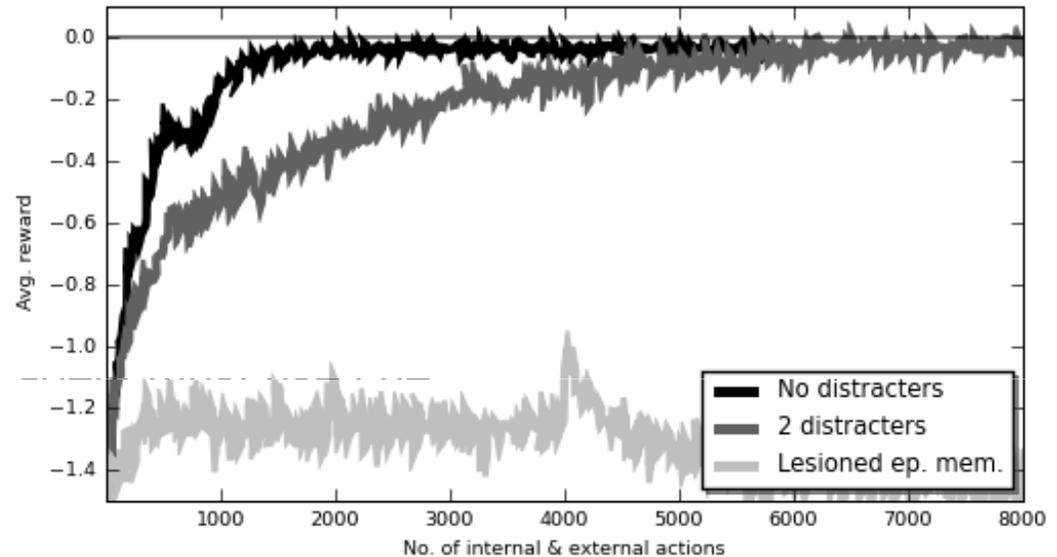
Agent drank from Well #1



When thirsty, the agent remembers what it did the last time that it was thirsty (and in this case, learns to move to the other well)

- ▶ Agent learns temporal control
 - Learns when to perform retrieval using current state of environment as cue
 - Then learns to retrieve what happened next

Learning to Construct a Compound Cue



- ▶ Agent learns
 - ▶ To perform multiple, consecutive retrievals which builds a compound cue
 - ▶ Which features to include in the compound cue

Nuggets of Gold, Chunks of Coal

- ▶ Demonstrated that an agent can learn to use EpMem
 - ▶ When to retrieve, which cue to use, temporal control, building a cue
 - ▶ An RL agent with EpMem can solve more problems
- ▶ Identified chicken-and-egg issue in learning to use memory
 - ▶ Learning to use EpMem can be challenging
- ▶ How can the persistence of retrievals be managed?
- ▶ How does EpMem compare to other memory mechanisms?

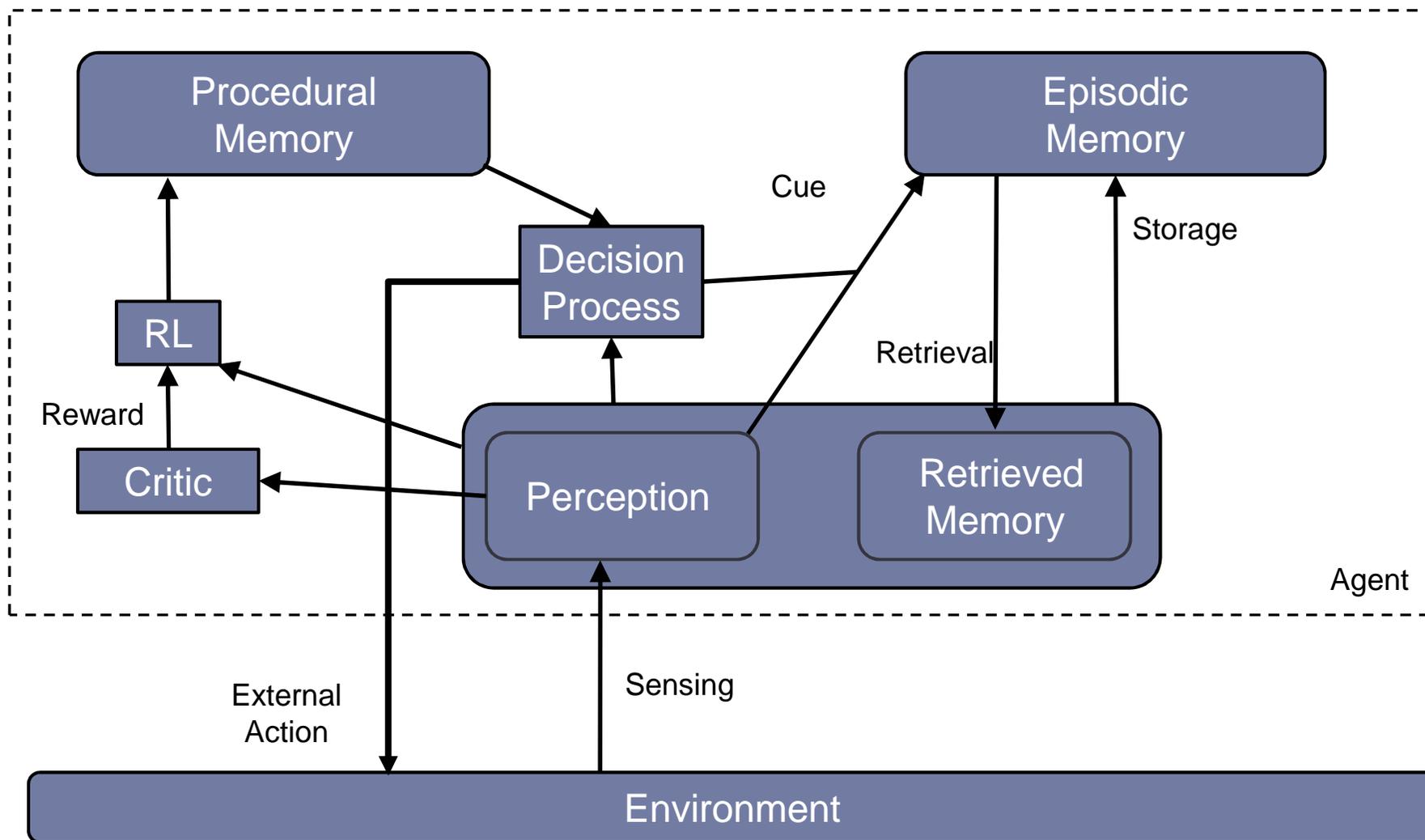


Bonus Slides Follow

Why Learn to Use EpMem?

- ▶ From a Soar perspective...
 - ▶ Integration of RL and EpMem components
 - ▶ Potential source of control knowledge for EpMem retrievals
- ▶ From a cognitive science perspective...
 - ▶ EpMem's contributions to task performance not typically modeled
 - ▶ Extends learning to *internal* actions
- ▶ From a machine learning perspective...
 - ▶ On-line, memory-less RL methods perform poorly in partially-observable settings
 - ▶ RL + memory can solve tasks that RL alone cannot
- ▶ Primary research questions:
 1. Can an agent learn to use EpMem while performing a task?
 2. What are the potential issues that arise when an agent learns to use memory?

A Framework for Learning to Use EpMem



Slide 18

NAG3

control s/b use?

Nicholas Gorski, 5/21/2009

A Soar Agent's View of Well World

▶ Input link:

```
<I2> ^agent <A1> ^object <O7>  
  ^gateway <G3> ^time 2  
  <A1> ^destination Well_1 ^drive <D1>  
    ^moving false ^name Agent ^x 1. ^y 0.  
  <D1> ^amount 1. ^type water  
  <O7> ^empty false ^name Well_1  
    ^resource water ^x 1. ^y 0.  
  <G3> ^destination Cave_shelter  
    ^name Well_1->Cave_shelter ^x 1. ^y 0.
```

▶ EpMem retrieval:

```
<R1001> ^io <I122> ^name temporal ^operator <O1157>  
  ^reward-link <R1003> ^parameters <p31>  
  <I122> ^input-link <I123> ^output-link <O1158>  
  <I123> ^agent A31 ^gateway <G318>  
    ^object <O1156> ^time 492  
  <A31> ^destination Well_2 ^drive <D92>  
    ^moving false ^name Agent ^x 0. ^y 1.  
  <D92> ^amount 0.55 ^type water  
  .... (object, gateway)  
  <O1157> ^name consume-resource ^resource Well_2  
  <P31> ^cues.cue water  
  <R1003> ^reward.value -2 ^reward.value -1
```

▶ Operators

▶ External actions

```
move-to Well_1  
move-to Cave_shelter  
consume-resource water
```

▶ Internal actions

```
retrieve-well water  
retrieve-well distracter
```

▶ Statistics

- ▶ 50-90 productions
- ▶ No impasses / subgoals