Integrating Semantic Memory in Soar

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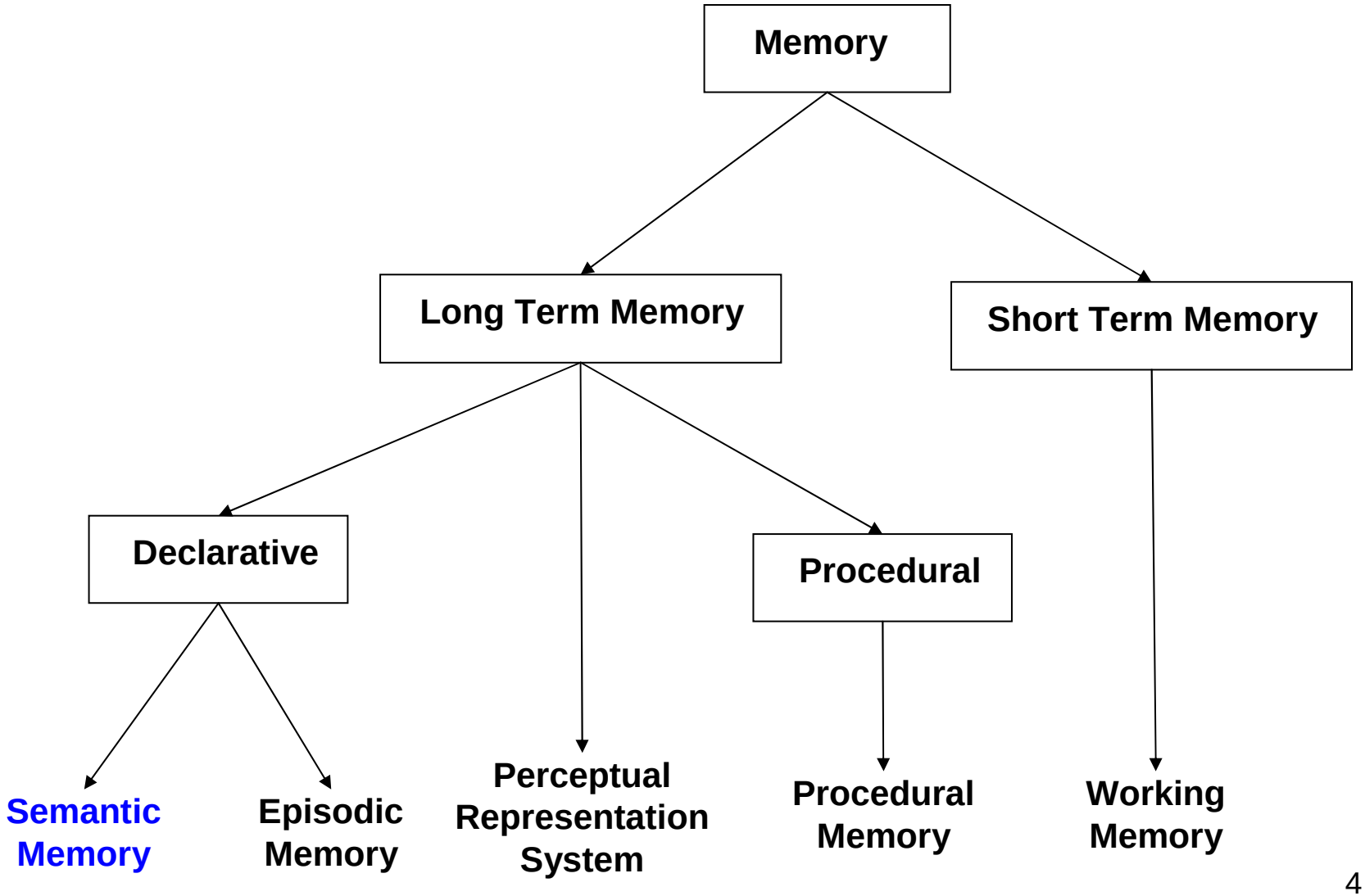
Outline

- Background & Motivation
- Implementations and Experiments

What is Semantic Memory

- Definition
  - ‘Your memory for meanings and general (impersonal) facts.’ [from WordNet]
- Episodic memory and Semantic memory distinction
  - Episodic memory
    - Tied to a specific learning episode or experience
    - What you remember
  - Semantic memory
    - General knowledge not tied to a learning experience
    - What you know

Memory Systems



Related Fields and Motivation

Architectures	Focus	Feature	Limitations
Cognitive Psychology (ACT-R)	To model human behavior	Long-term declarative memory and learning	Haven't been used to build functional agents
AI Agent Architectures (Soar)	To build intelligent agents	Efficient domain knowledge engineering	No long-term semantic memory, limited learning
Knowledge Representation Systems (CYC)	To represent common sense semantic knowledge	Declarative knowledge representation	Representational model, not learning model
Our Approach (Soar + semantic memory)	To build intelligent agents	Efficient domain knowledge engineering and more learning capabilities	Constrained by Soar

Research Goals

- To improve general functionality of Soar by semantic memory
  - Explore new cognitive capabilities
  - Characterize computational functionalities
- To understand semantic memory in the context of a general cognitive architecture
  - How to use semantic memory in specific tasks?
  - How semantic memory interacts with other mechanisms in Soar?
  - What are the computational implications of semantic memory and episodic memory distinction?

Distinction Between Semantic Memory and Episodic Memory in Soar

	Semantic Memory	Episodic Memory
Storage & retrieval unit	Single level objects in working memory (declarative chunks)	Entire working memory snapshot (episode)
Temporal information	No architectural temporal information	Architectural temporal information (ex: next episode)
Main purposes	Store general knowledge Category learning	Store specific events Case-based reasoning

Outline

- Background & Motivation
- Implementations and Experiments
  - Task: Cognitive Arithmetic

Overview of Experiment

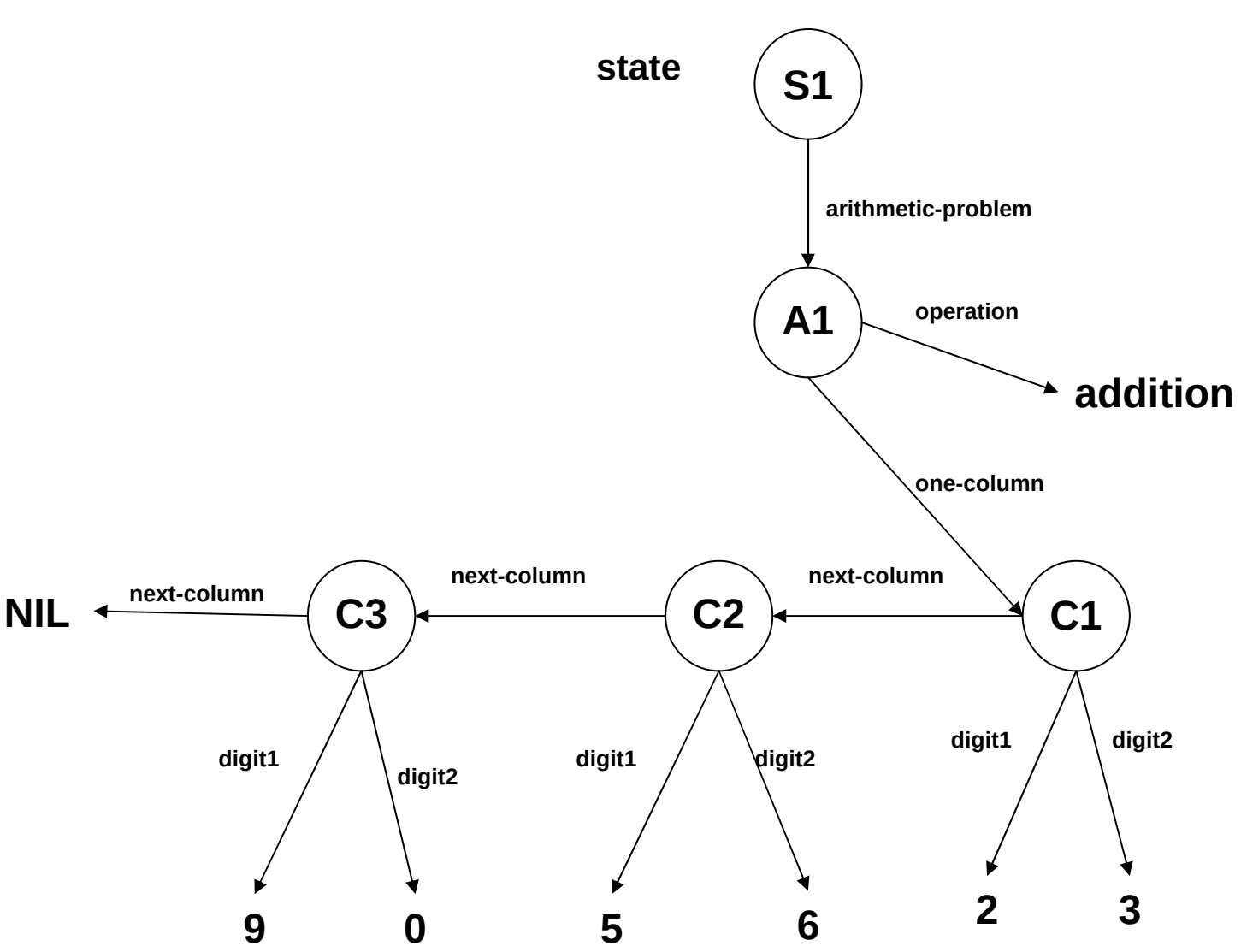
- Purpose:
  - Integrate a declarative semantic memory component
  - Demonstrate related functional advantage of declarative representation
- Implementation:
  - Semantic memory with declarative representation
  - Deliberate and automatic semantic learning
- Task: Cognitive arithmetic
  - Easy to understand
  - Universally performed
  - Multiple types of learning

0 9 5 2

+ 0 0 6 3

1 0 1 5

Working Memory Representation of an Arithmetic Problem



0 9 5 2

\+ 0 0 6 3

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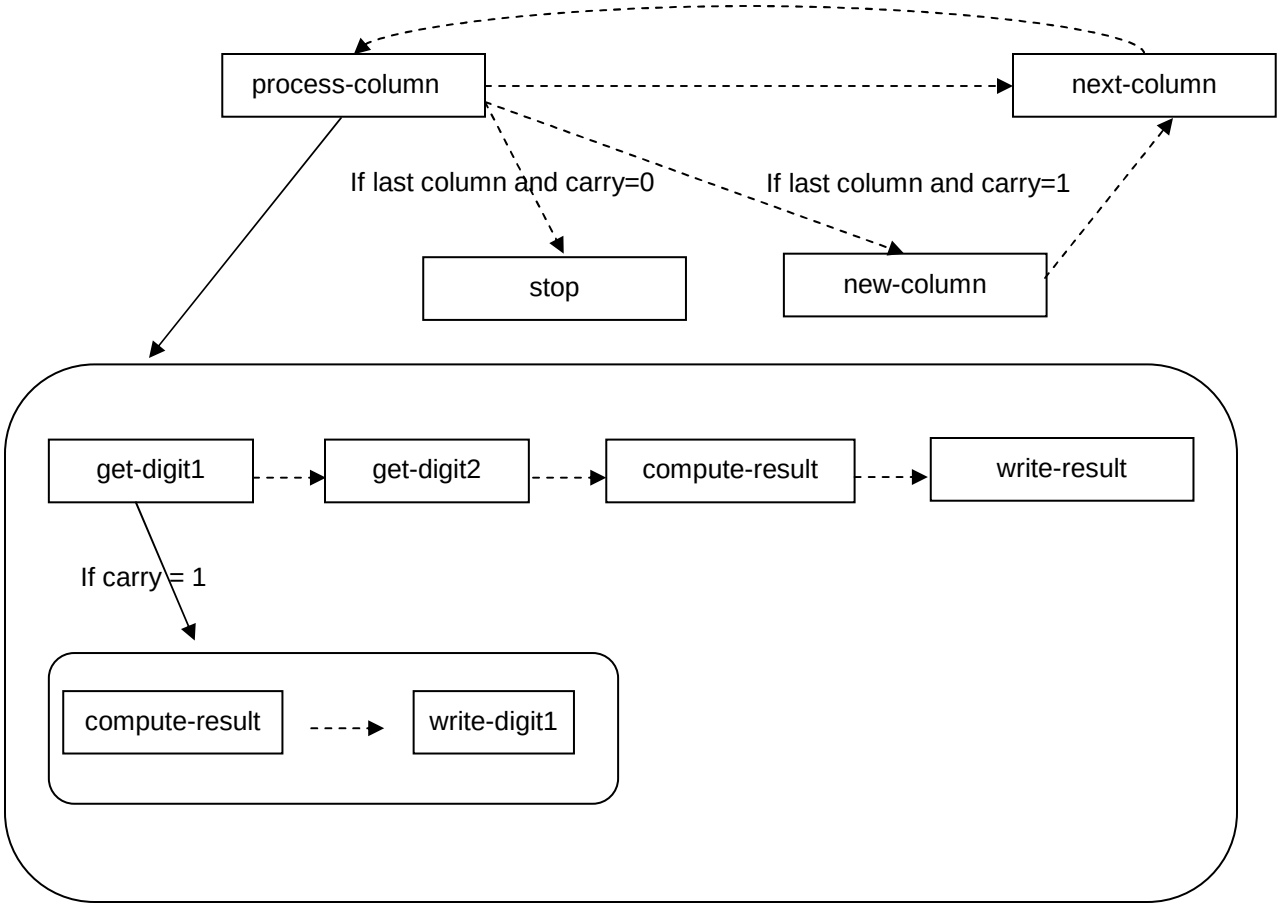
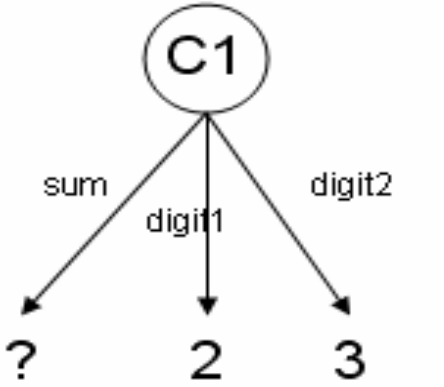
1 0 1 5

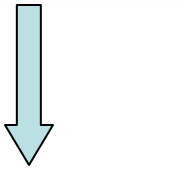
Problem Space



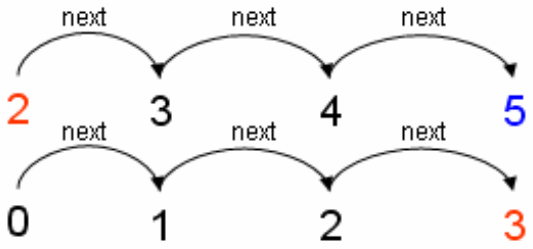
Solving One Column



An unknown sub-problem



General procedural knowledge

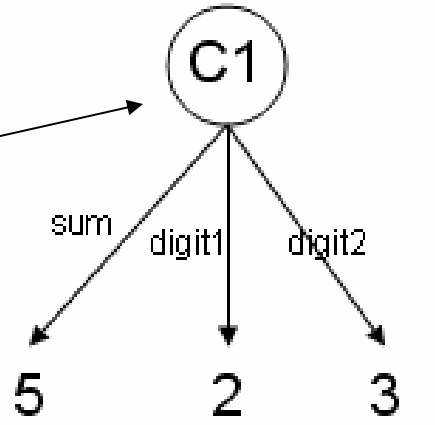


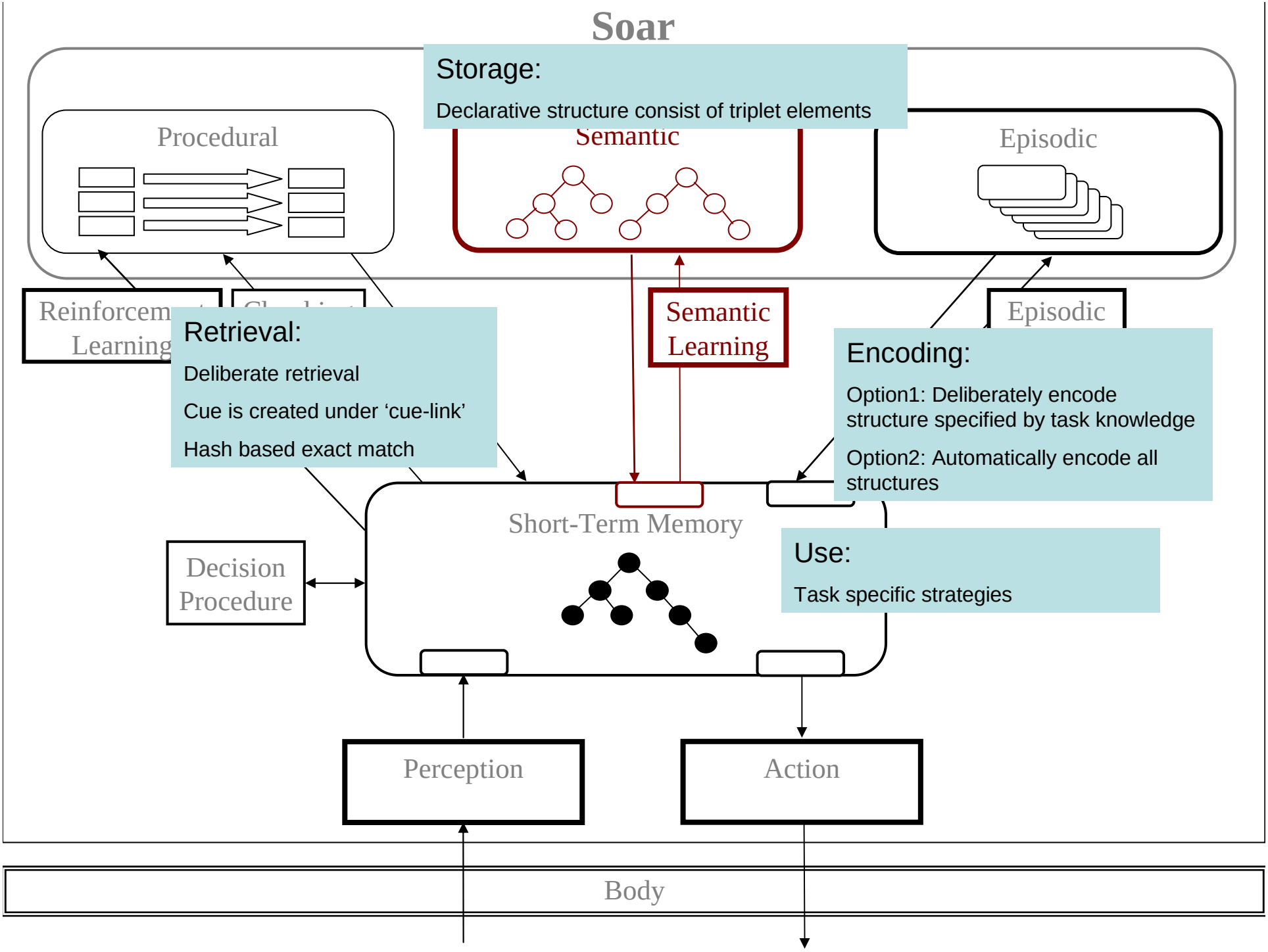
Chunking learns a rule

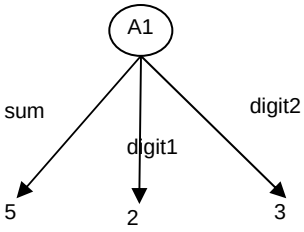
```
sp {chunk-1
   (state <s> ^digit1 2
              ^digit2 3)
-->
   (<s> ^sum 5)
}
```

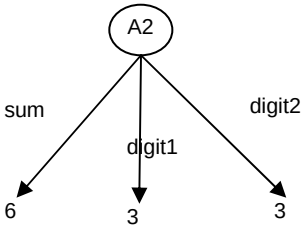
Compare

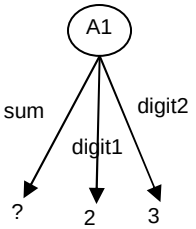
Semantic learning

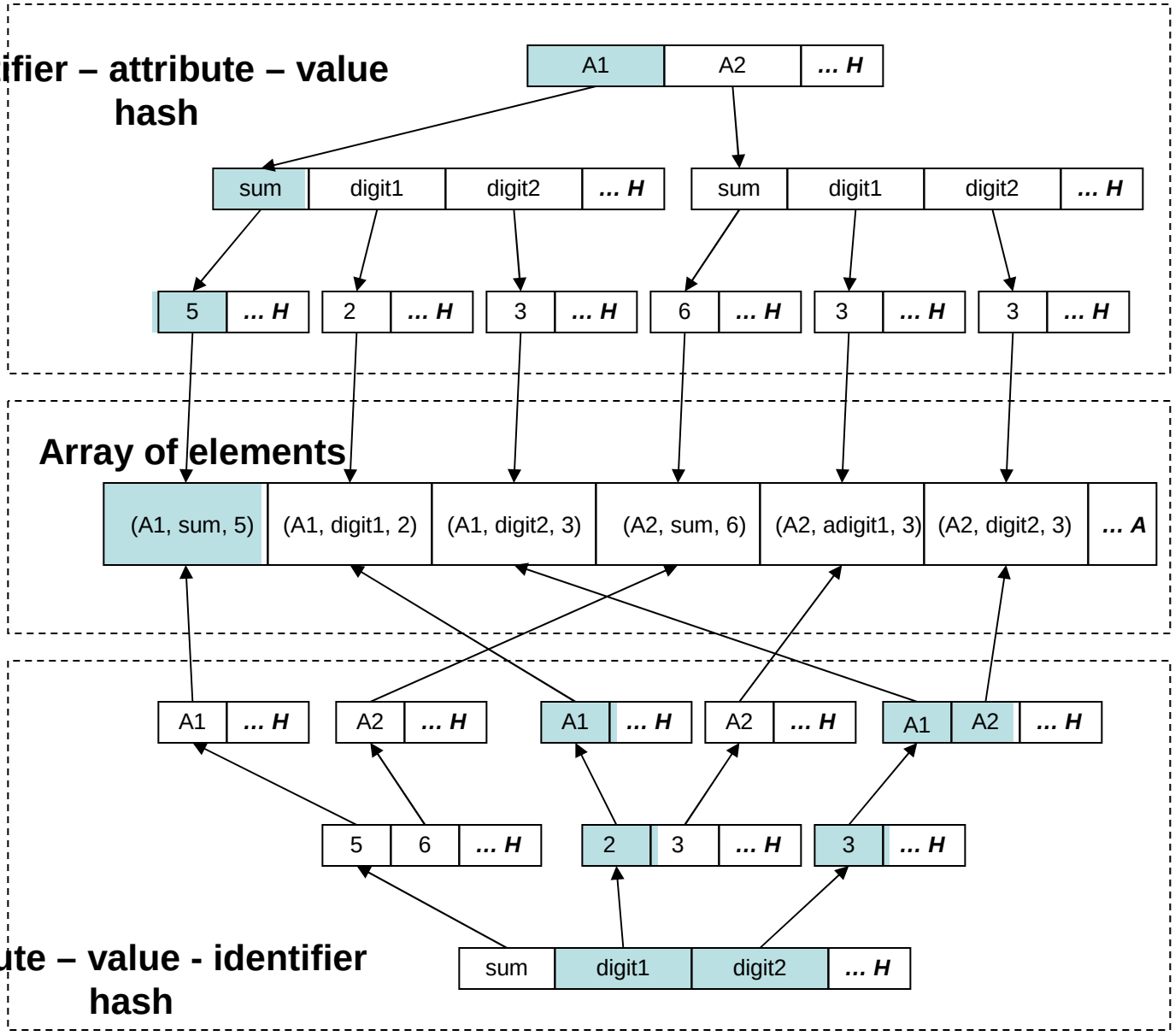



Soar
Storage:
Declarative structure consist of triplet elements
Procedural
Semantic
Episodic
Reinforcement Learning
Semantic Learning
Episodic
Retrieval:
Deliberate retrieval
Cue is created under ‘cue-link’
Hash based exact match
Encoding:
Option1: Deliberately encode structure specified by task knowledge
Option2: Automatically encode all structures
Short-Term Memory
Use:
Task specific strategies
Decision Procedure
Perception
Action
Body

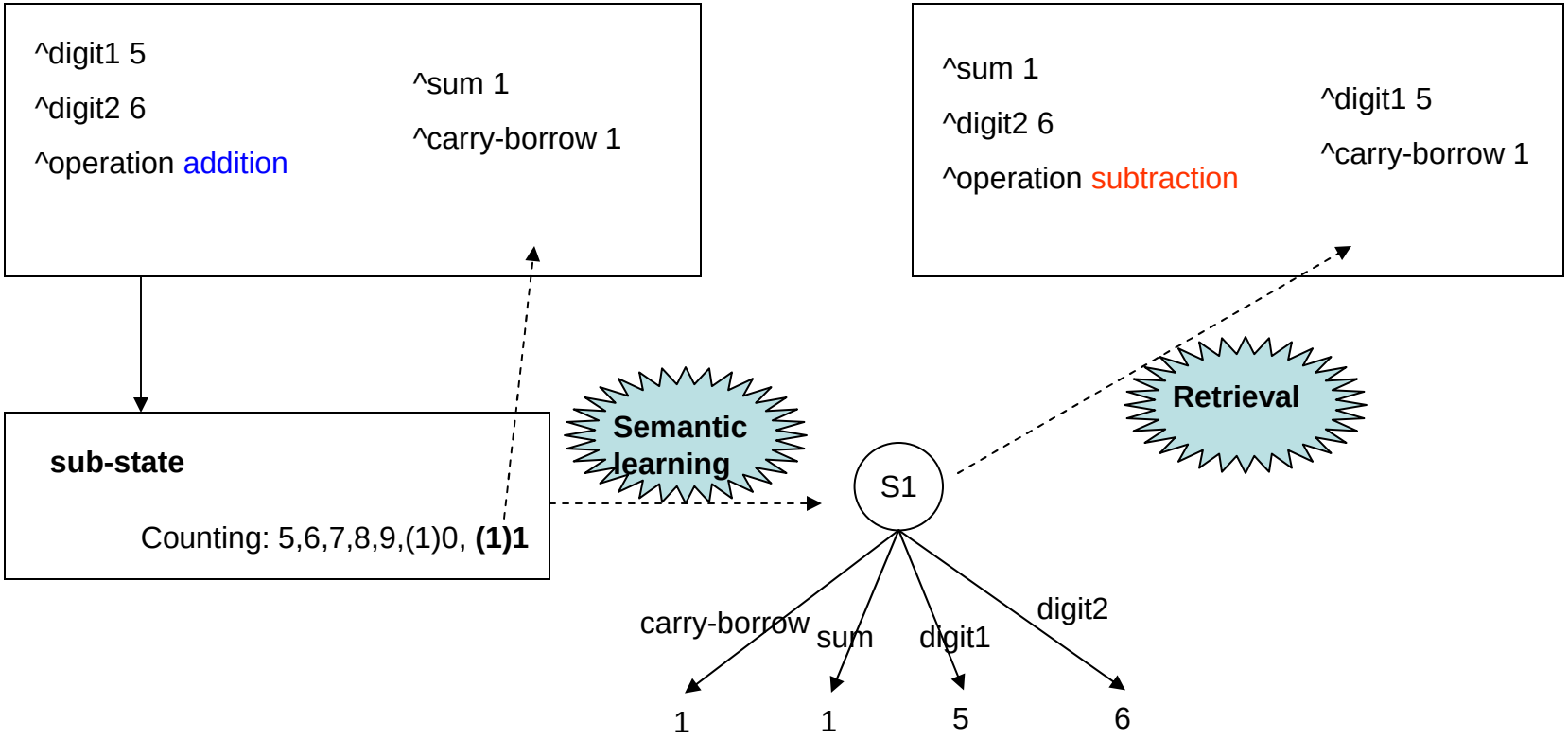

A1
sum
digit1
digit2
5
2
3


A2
sum
digit1
digit2
6
3
3


A1
sum
digit1
digit2
?
2
3

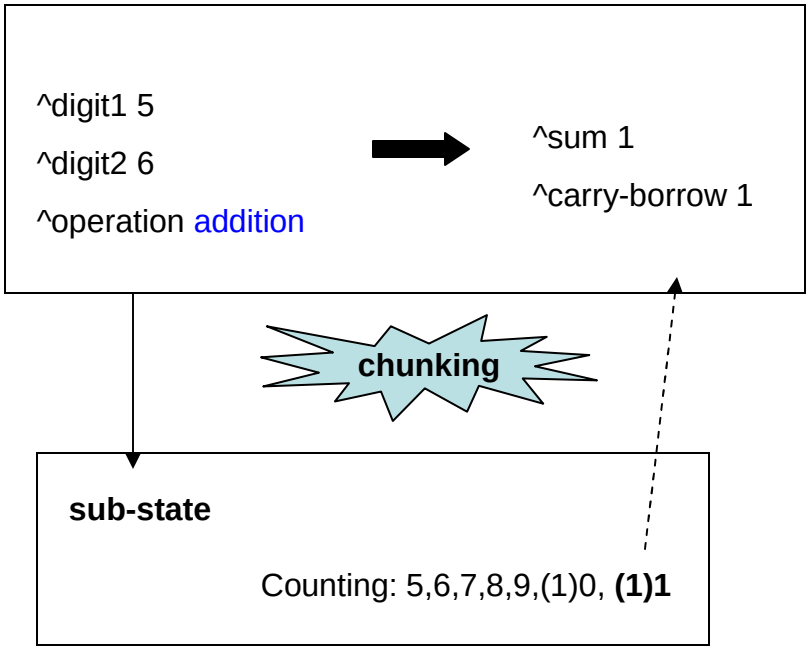

Identifier – attribute – value hash
A1
A2
... H
sum
digit1
digit2
... H
5
2
3
6
3
3
Array of elements
(A1, sum, 5)
(A1, digit1, 2)
(A1, digit2, 3)
(A2, sum, 6)
(A2, adigit1, 3)
(A2, digit2, 3)
... A
5
6
2
3
3
Attribute – value - identifier hash

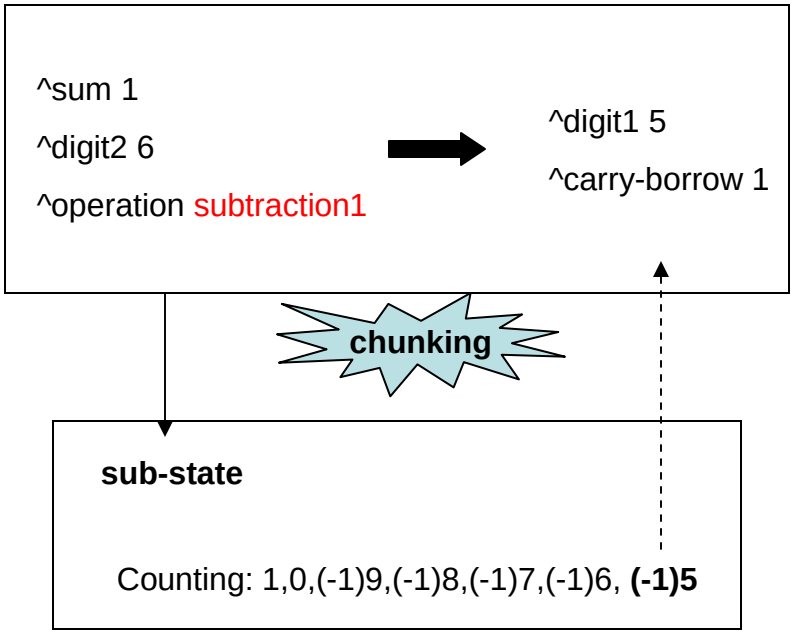
Transfer Learning Effect from Semantic Learning



Counting once and learn 1 declarative chunk

Procedural Representation Cannot be Transferred

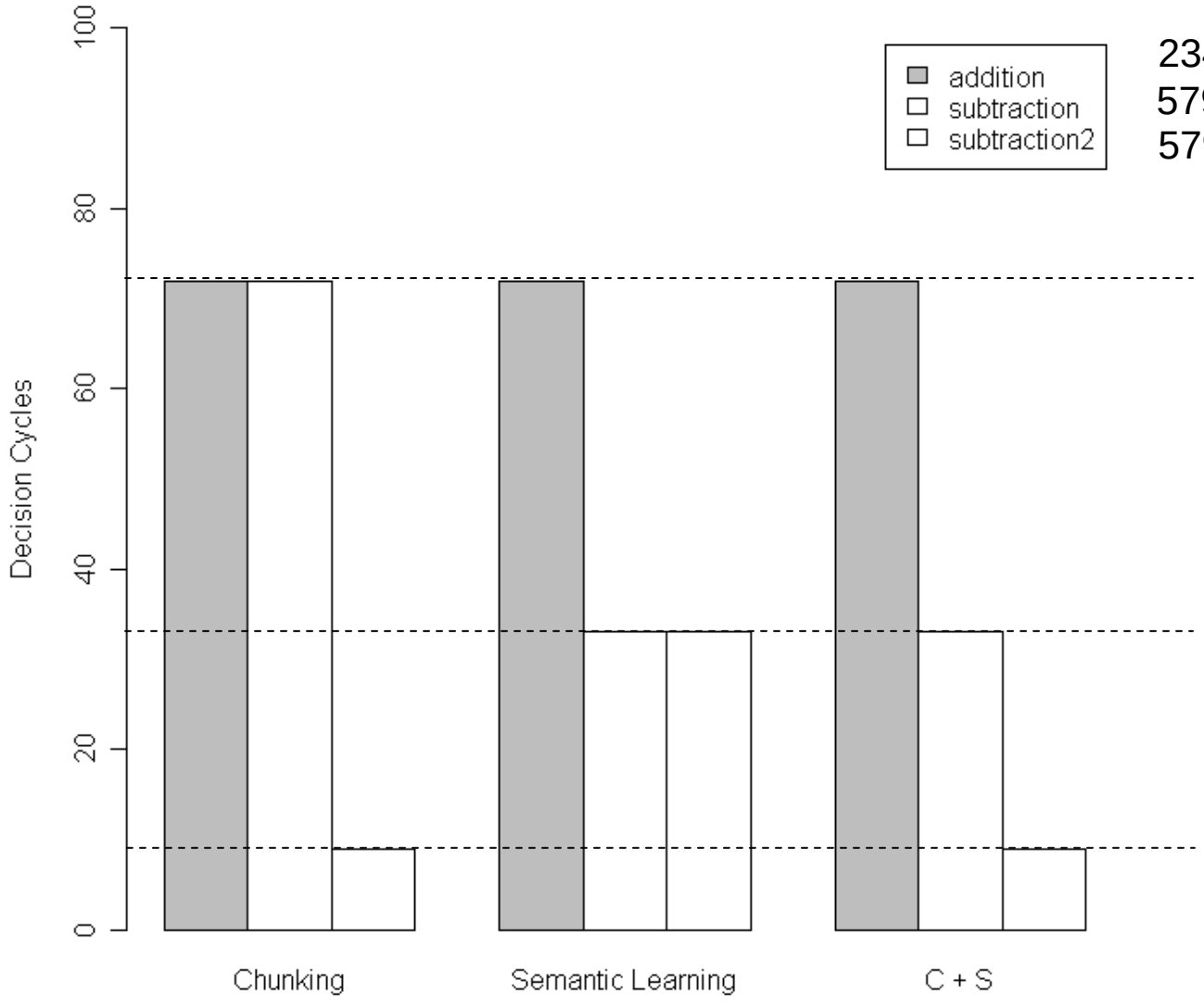





```
sp {chunk-1
   (state <s> ^digit1 5
              ^digit2 6)
-->
   (<s> ^sum 1
        ^carry-borrow 1)
}
```

Counting twice and learn 2 rules

Comparison of Different learning Configurations



234 + 345 = 579
579 – 345 = 234
579 – 345 = 234

Decision Cycles Breakdown

Situations / Decision Cycles / Operators	All computations	With arithmetic facts	After chunking
operators in top-state (initialization, process-column, next-column)	9	9	9
get-digits (from top-state)	3×3=9	9	0
write-result (to top-state)	3×1=3	3	0
retrieve	3×4=12	12	0
counting	39	0	0
Total	72	33	9

Summary

- Nuggets
  - Implemented a semantic memory with declarative representation
  - Demonstrated the functional advantage of declarative representation over procedural representation
  - Demonstrated transfer learning effect by semantic learning
  - Demonstrated the functional Interaction between semantic learning and chunking
- Coals
  - Cognitive arithmetic is an internal mental task
  - The task is completely deterministic

Thank You