A Unified Approach to Diverse Forms of Action Modeling

Can you teach an old cognitive architecture new tricks?

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Different Memories and Processes

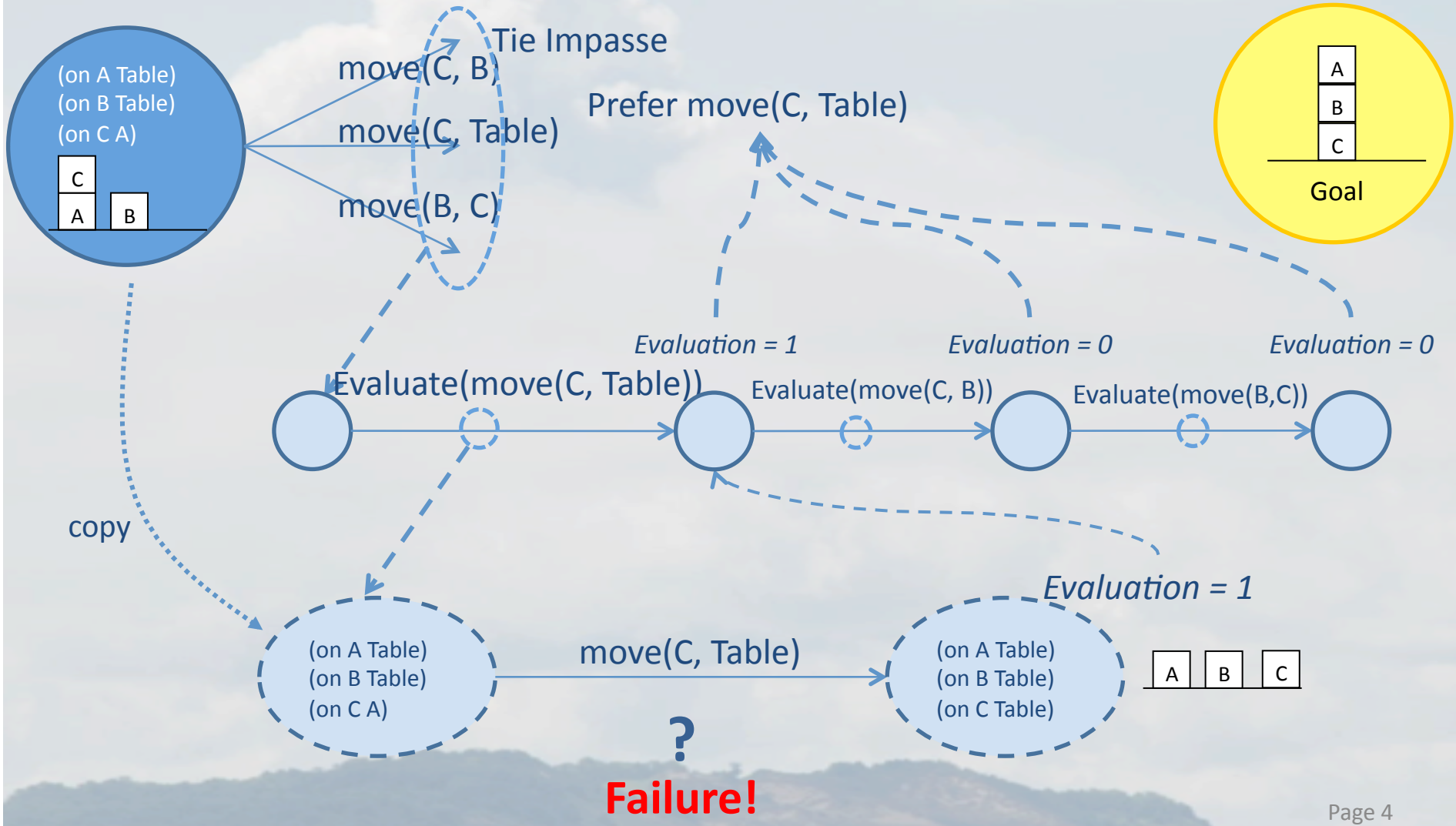
1. Procedural Knowledge	(Rules)	Qualitative Simulation
2. Episodic Knowledge	(Memories)	Memory-based Reasoning
3. Semantic Knowledge	(Facts)	
4. Mental Imagery	(Simulation)	Mental Simulation
5. Action Decomposition		
6. Combinations of Above		

- Prior Research: Forbus and Gentner, "Qualitative Mental Models: Simulations or Memories."
- Hypothesis: General agents should use whatever mechanisms (and knowledge) are available.
- Question: How can these different mechanisms be used for action modeling within a cognitive architecture ?

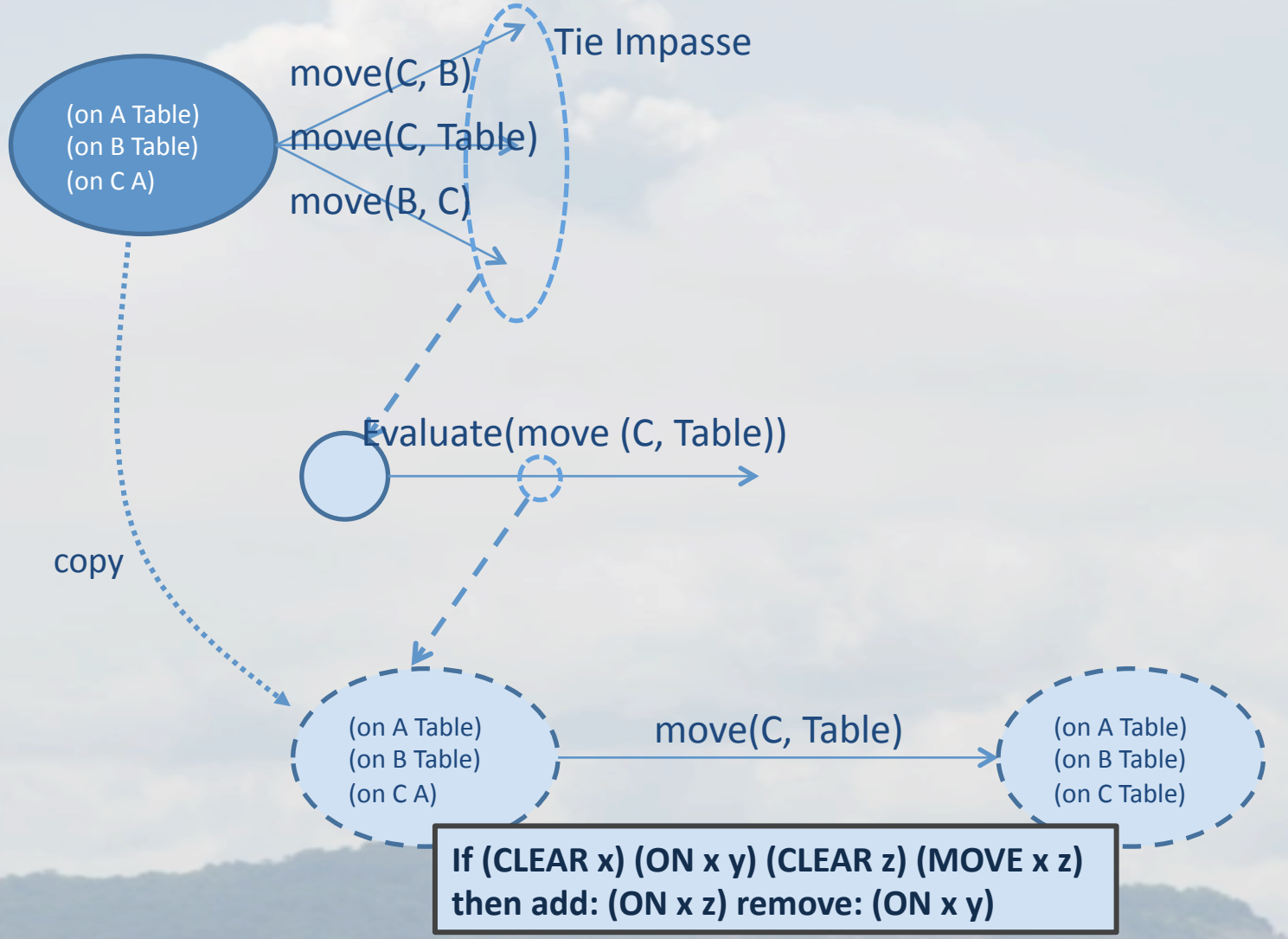
Basic Ideas

- Agent is trying to select **actions**
- If knowledge is incomplete/low confidence
  - Use **action modeling** for one-step look-ahead
  - Use impasse-driven subgoals to access different **action modeling mechanisms**
  - Evaluate/compare results to make decision

High Level View of Action-Model-Based Prediction in Soar



Action Modeling via Rules

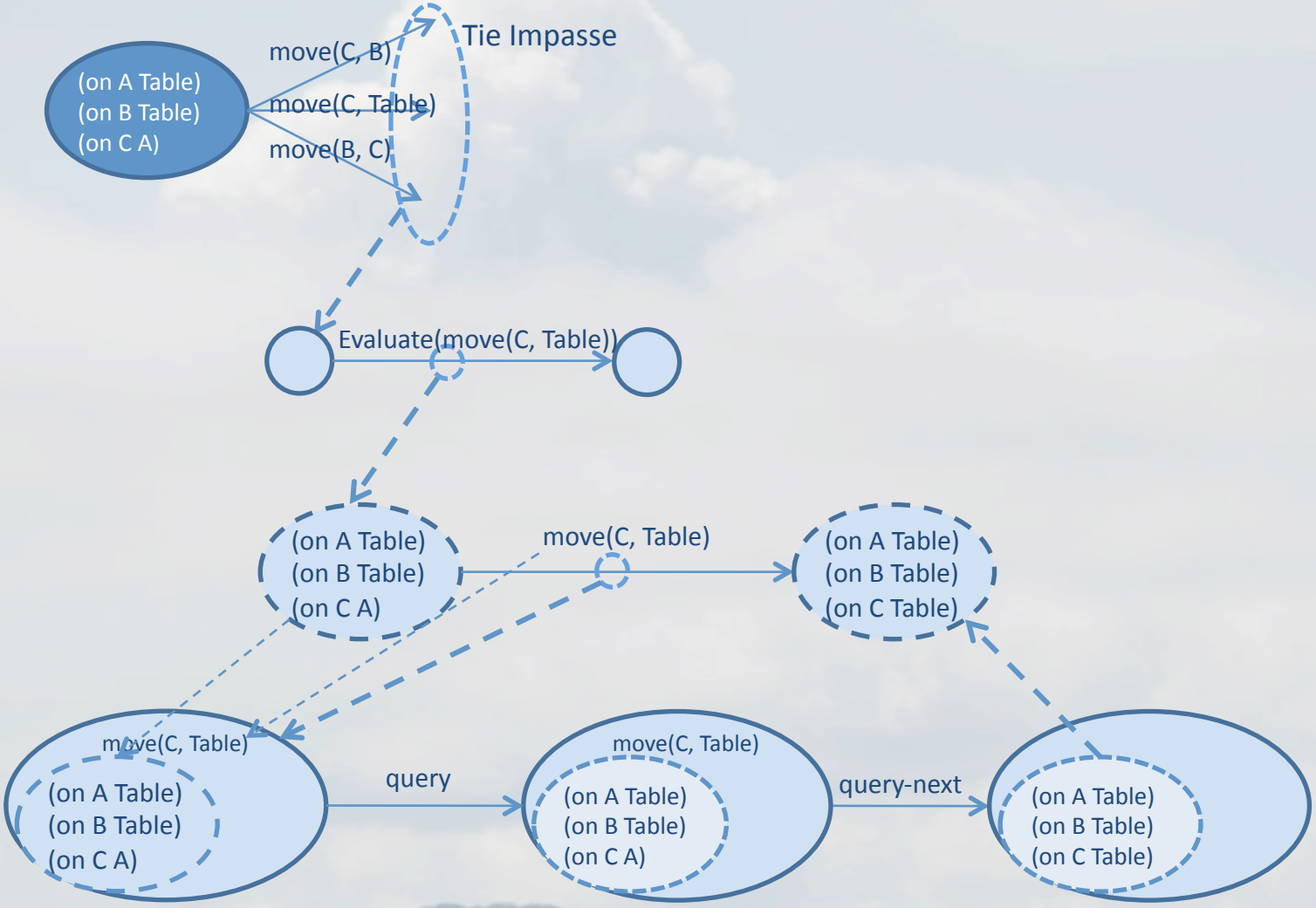


Action Modeling via Episodic Memory

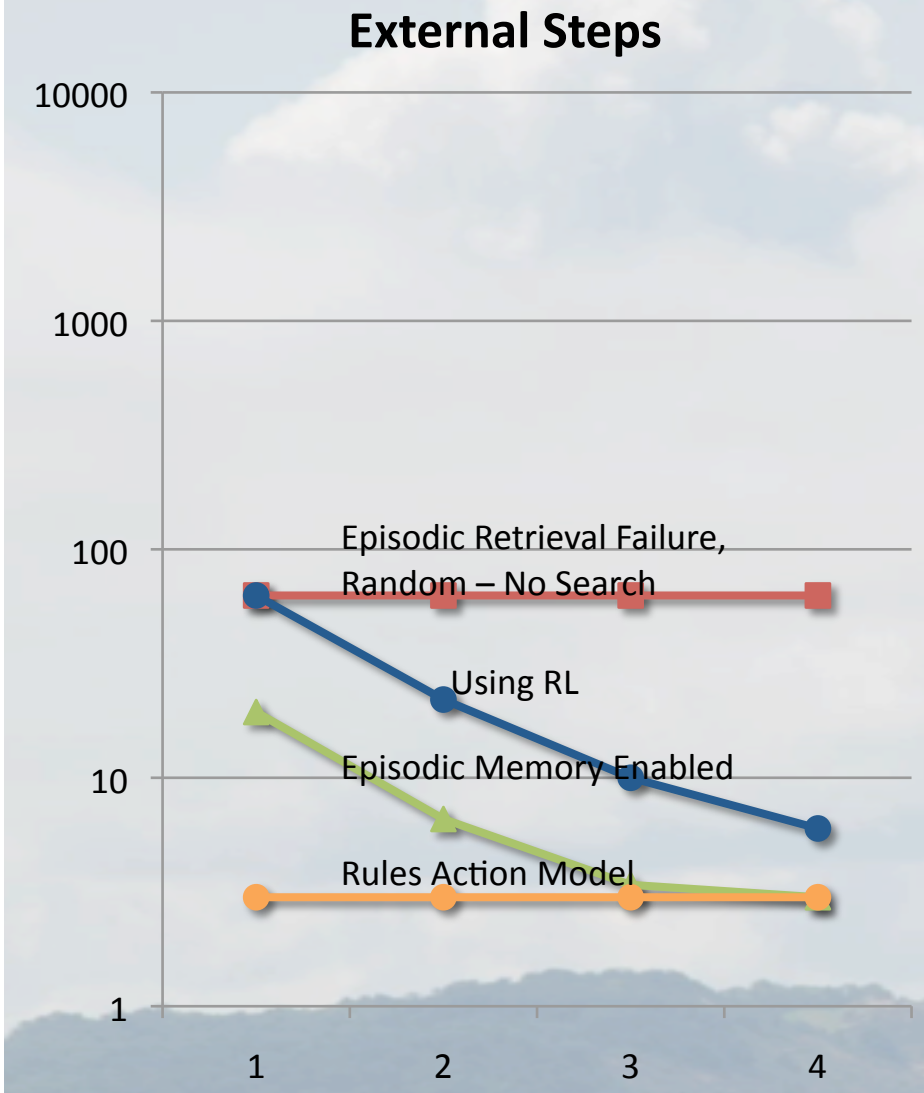
Using memory of past events to project the future.

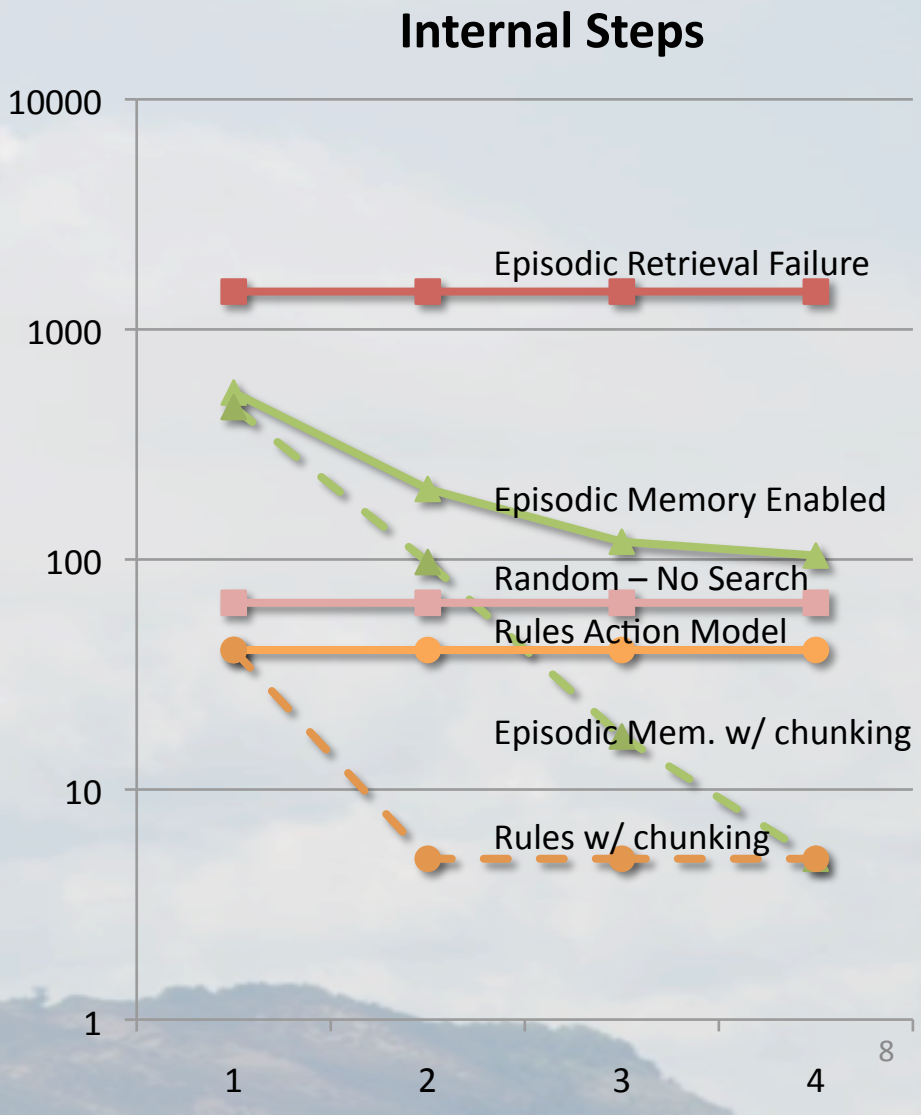
- Restricted to similar situations
- Explicit generalization possible via analogy
  - (Xu & Laird, 2010)
- Lots of algorithms to make it efficient
  - (Derbinsky & Laird, 2009)

Action Modeling via Episodic Memory



Results with Action Modeling via Episodic Memory



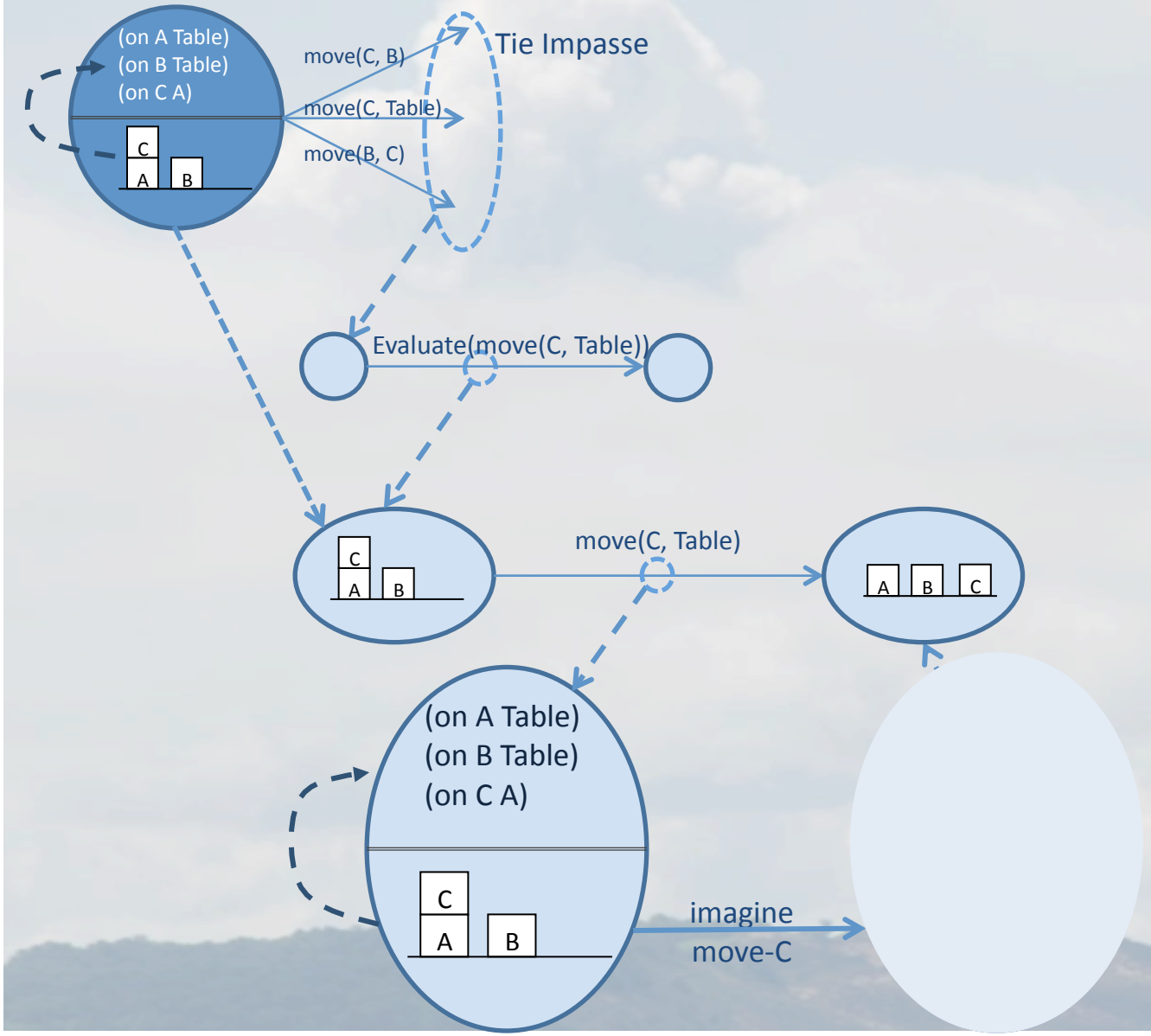


Action Modeling via Mental Imagery

Using imagery to predict results of actions.

- Limited to spatial situations.
- Assumes *innate* knowledge of effects of *simple* actions on spatial (non-symbolic) representation.
  - Translation, rotation, collision, …
- Can generalized to using a physics-based simulation engine (Zickler, 2010)

Action Modeling via Mental Imagery



Action Modeling via Semantic Memory

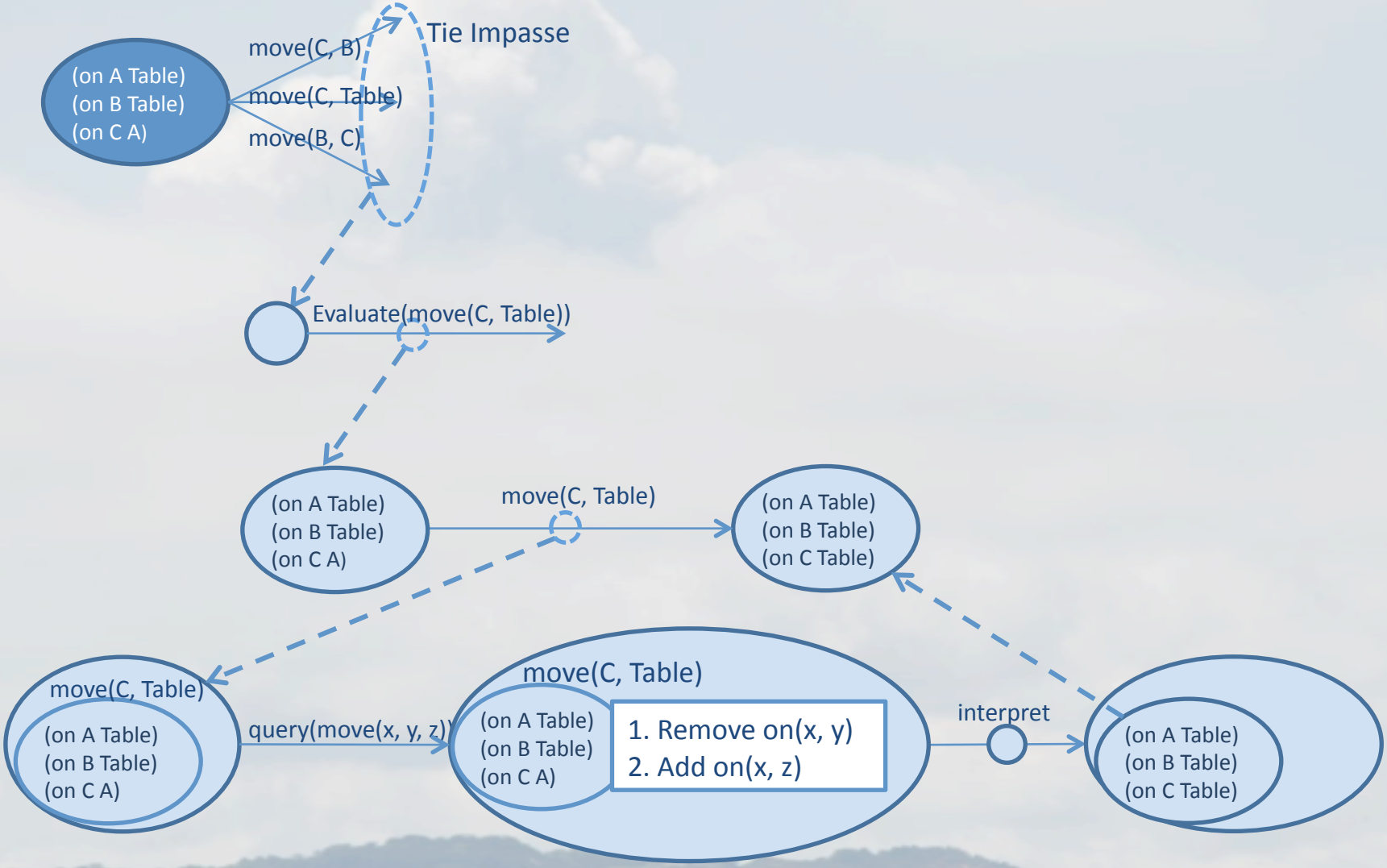
Possible sources of semantic knowledge:

- Read it in a book
- Somebody told you
- You watched someone else and "took notes"
- You generalized from specific instances yourself

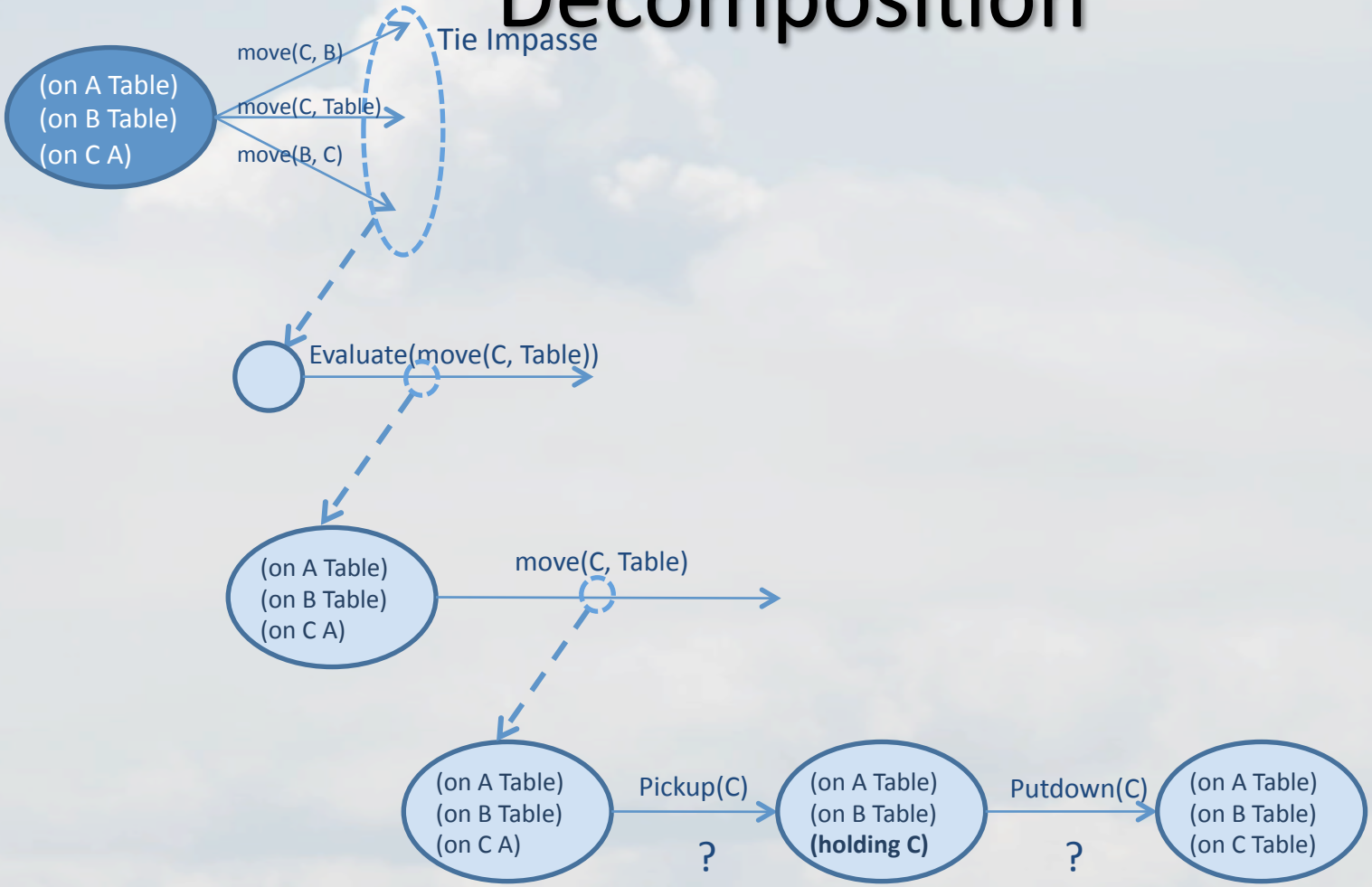
Requires knowledge to *interpret* semantic knowledge

Implemented in Soar as operators in substate

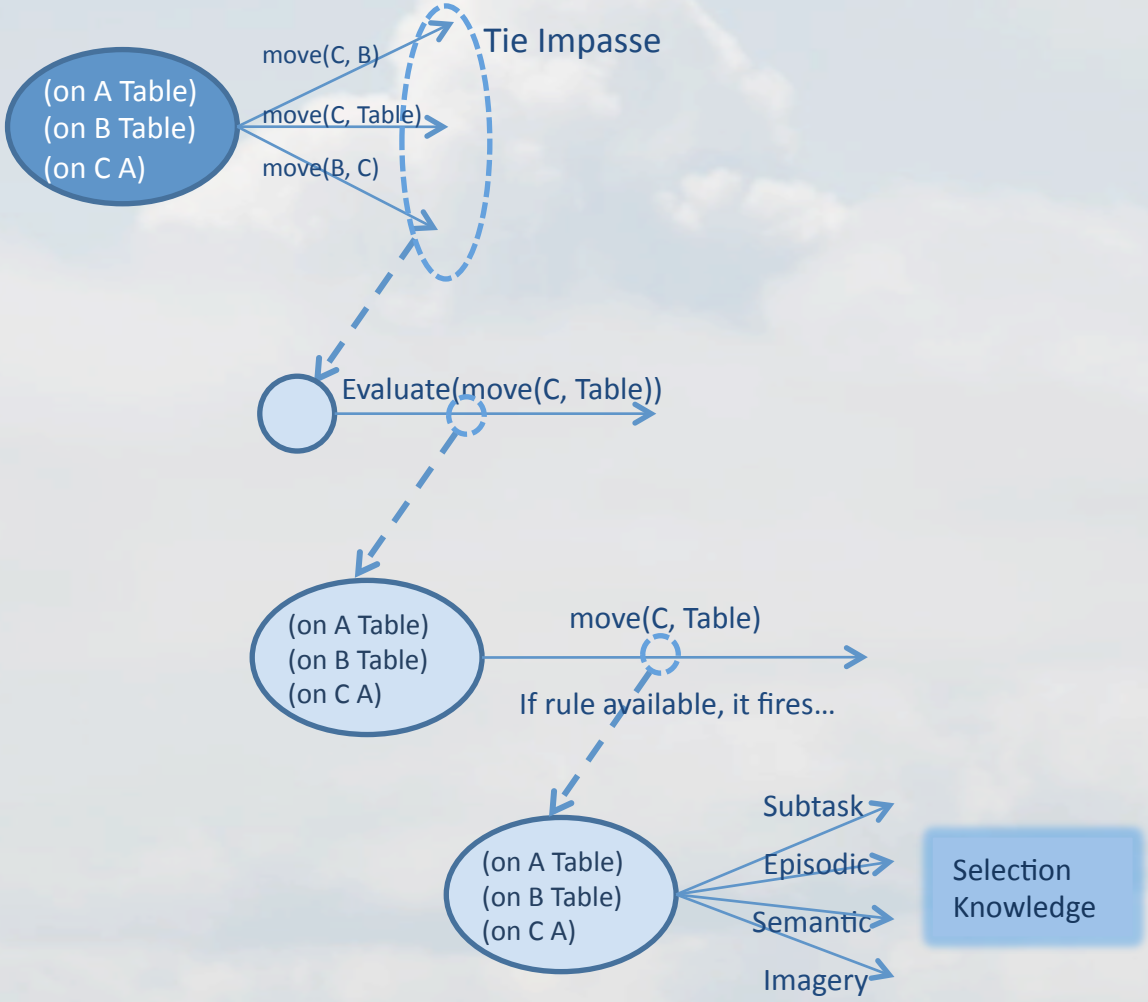
Action Modeling via Semantic Memory



Action Modeling via Operator Decomposition

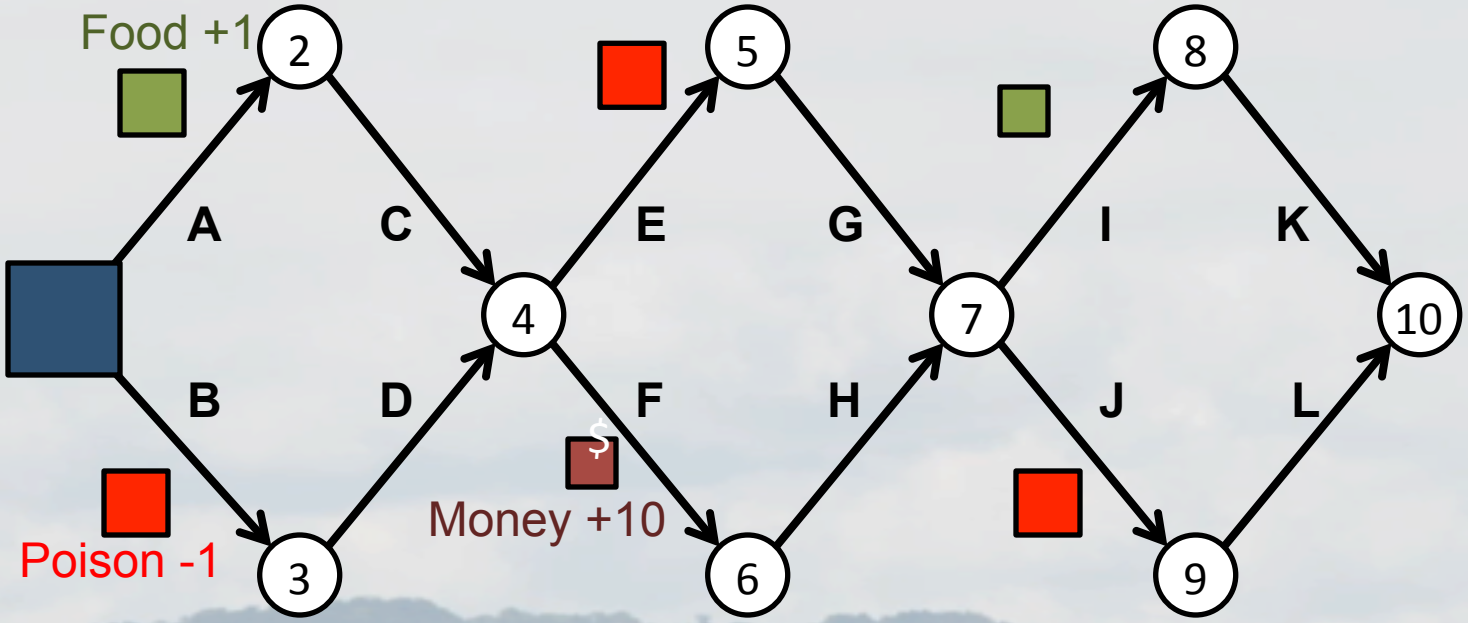


Choosing which Approach

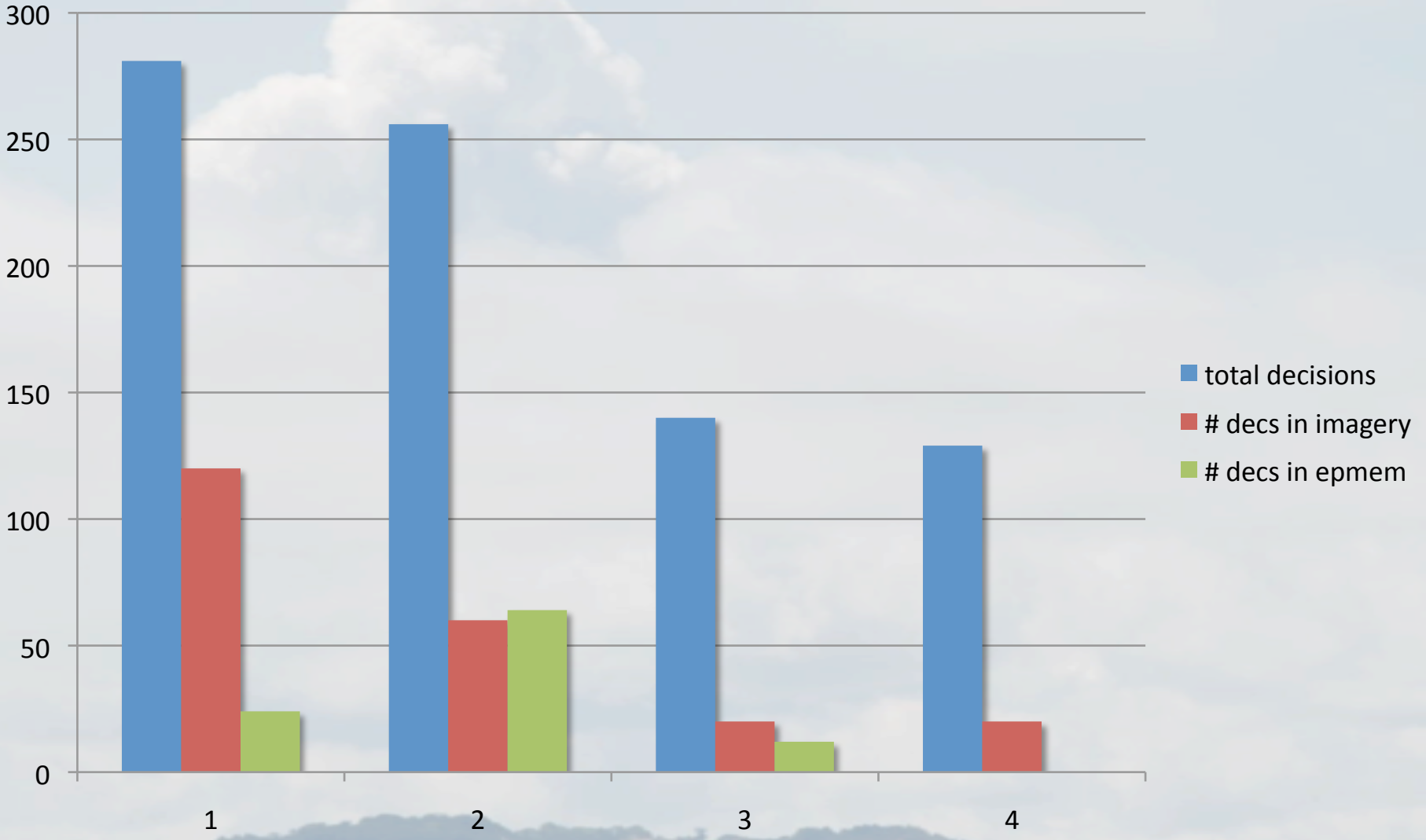


Simple Board Game Task

Agent knows value of $ (stored in semantic memory), but does not know value of food or poison.



Results across four trials



Summary of Knowledge Characteristics

- Rules
  - Fast, implicit (not reportable)
  - Specificity depends on learning/programming
  - Created by hand or learned through chunking
  - Transitions to selection rules through chunking
- Episodic memory
  - Slow, explicit (reportable)
  - Usually specific
  - Built up automatically through experience
  - Transitions to rules through chunking
- Semantic memory
  - Slow, explicit (reportable)
  - Usually general
  - Built up through experience (but we don't have good models of that yet)
  - Transitions to rules through chunking
- Mental imagery
  - Slowest (many internal steps), explicit (reportable)
  - General if problem involves spatial reasoning
  - Requires knowledge to map actions onto spatial operators
  - No learning necessary, except above
  - Does not transition to rules through chunking
- Decomposition
  - Slow, explicit (reportable)
  - Generality depends on task
  - Don't have theory of how decomposition is learned
  - Transitions to rules through chunking

Predictions & Observations

- **Novel tasks**
  - Exploration if no knowledge is available
  - Imagery if spatial
  - Semantic knowledge as available

- **Repeated tasks**
  - Behavior speeds up by
    1. Episodes for exact situations (and mental imagery)
    2. Compiling to rule-based action model
    3. Replacing look ahead with selection rules

Differential reporting of how decision was made and what was used to make decision.

Differential brain activation based on task characteristics and human experience.

Gold and Coal

1. Support many different types of knowledge for action modeling
2. Partial story as to how action modeling knowledge is learned
3. Falls out of structure of Soar
   - Does not require any changes to Soar
4. Unresolved how to choose which method