Artificial Cognitive Systems

Module 3: Cognitive Architectures

Lecture 5: the Common Model of Cognition.

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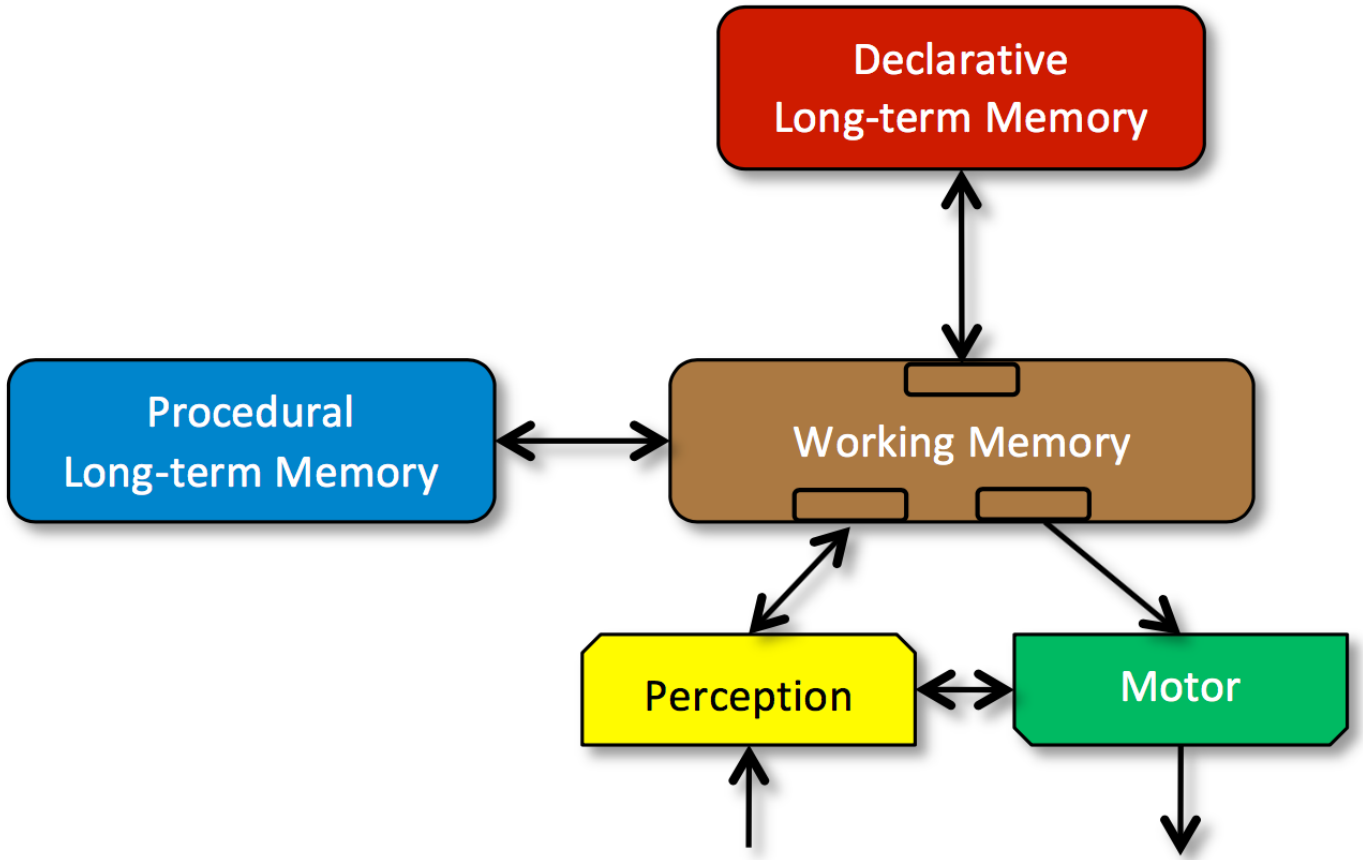
A Standard Model of the Mind



A Common Model of Cognition

AAAI 2018 Fall Symposium on
A Common Model of Cognition
October 18-20, Westin Arlington Gateway
Arlington, Virginia

Home

Organizing Committee

Call for Participation

Registration

Schedule

2017 AAAI Fall Symposium on a 'Standard Model of the Mind'

2017 Schedule and Slides

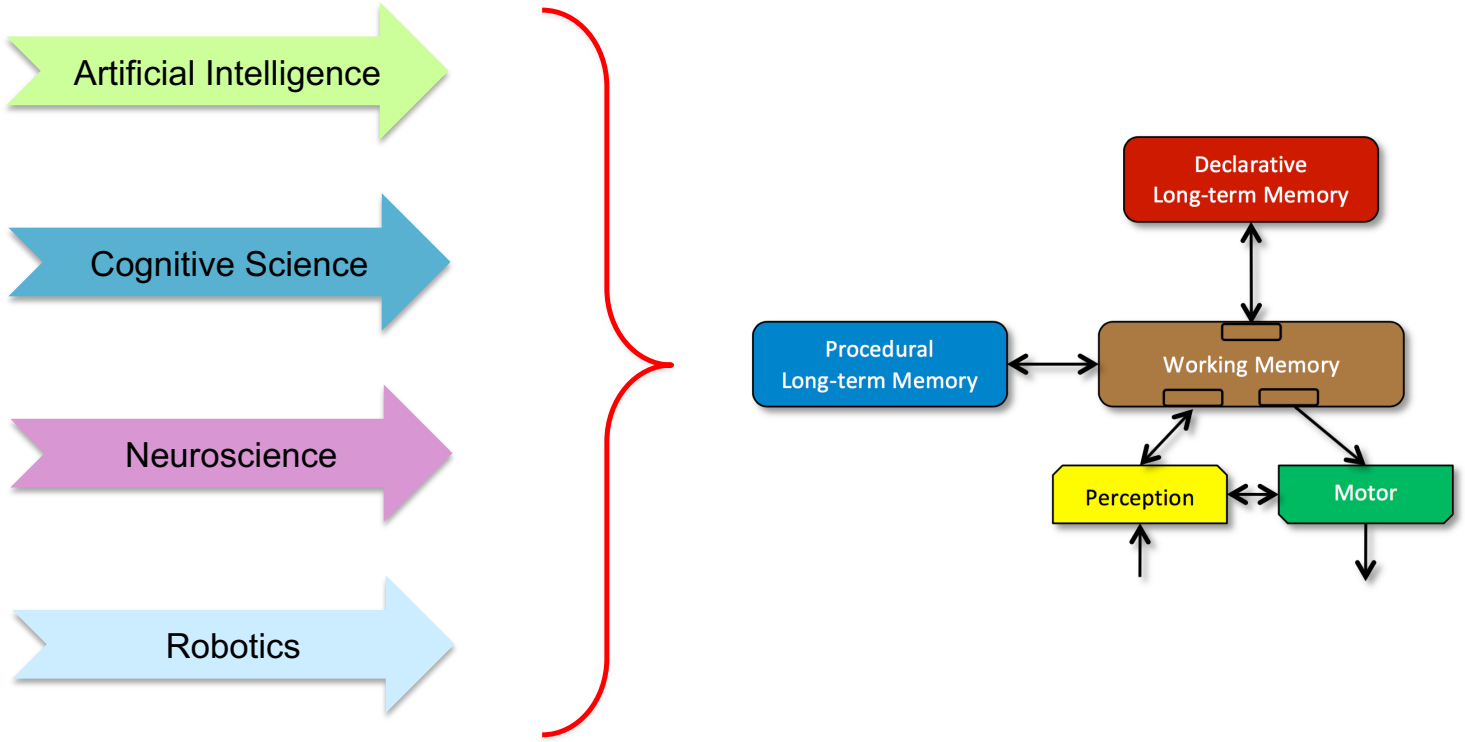
2018 AAAI Fall Symposium on 'A Common Model of the Cognition'

A mind is a functional entity that can think, and thus support intelligent behavior. Artificial intelligence, cognitive science, neuroscience, and robotics all contribute to our understanding of minds, although each draws from a different perspective. Artificial intelligence concerns building artificial minds, and thus cares most about how systems can be built that exhibit intelligent behavior. Cognitive science concerns modeling natural minds, and thus cares most about understanding cognitive processes that yield human thought. Neuroscience concerns the structure and function of brains, and thus cares most about how brains induce minds. Robotics concerns building and directing artificial bodies, and thus cares most about how minds control such bodies.

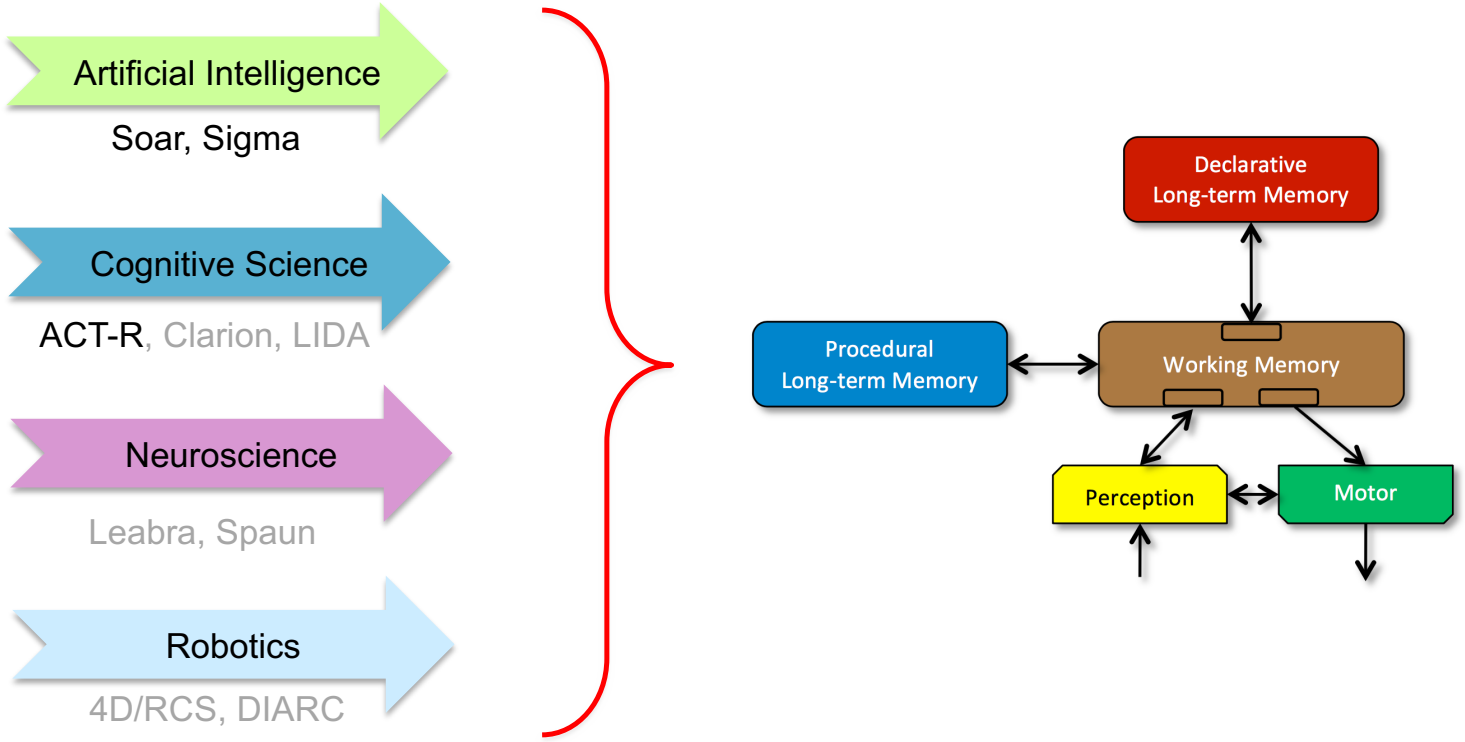
Will research across these disciplines ultimately converge on a single understanding of mind? This is a deep scientific question to which there is as yet no answer. However, there must at least be a single answer for cognitive science and neuroscience, as they both investigate the same mind, or narrow class of minds, albeit at different levels of abstraction. Research that is inspired by natural systems also may fit within this class of minds, particularly if it is slightly abstracted; but so too may research that has no such aspiration yet still finds itself in the same neighborhood for functional reasons. This broader class comprises what can be called human-like minds.

Our goal with this symposium is to engage the international research community in developing *A Common Model of Cognition;* that is, a community consensus concerning the mental structures and process implicated in human-like minds to the extent that such a consensus exists. The intent, at least for the foreseeable future, is not to develop a single implementation or model of cognition by which everyone concerned with human-like cognition would abide, or even a theory in which all of the details are agreed to as correct. What is sought though is a statement of the best consensus given the community's current understanding of cognition, plus a sound basis for further refinement as more is

A Common Model of Cognition

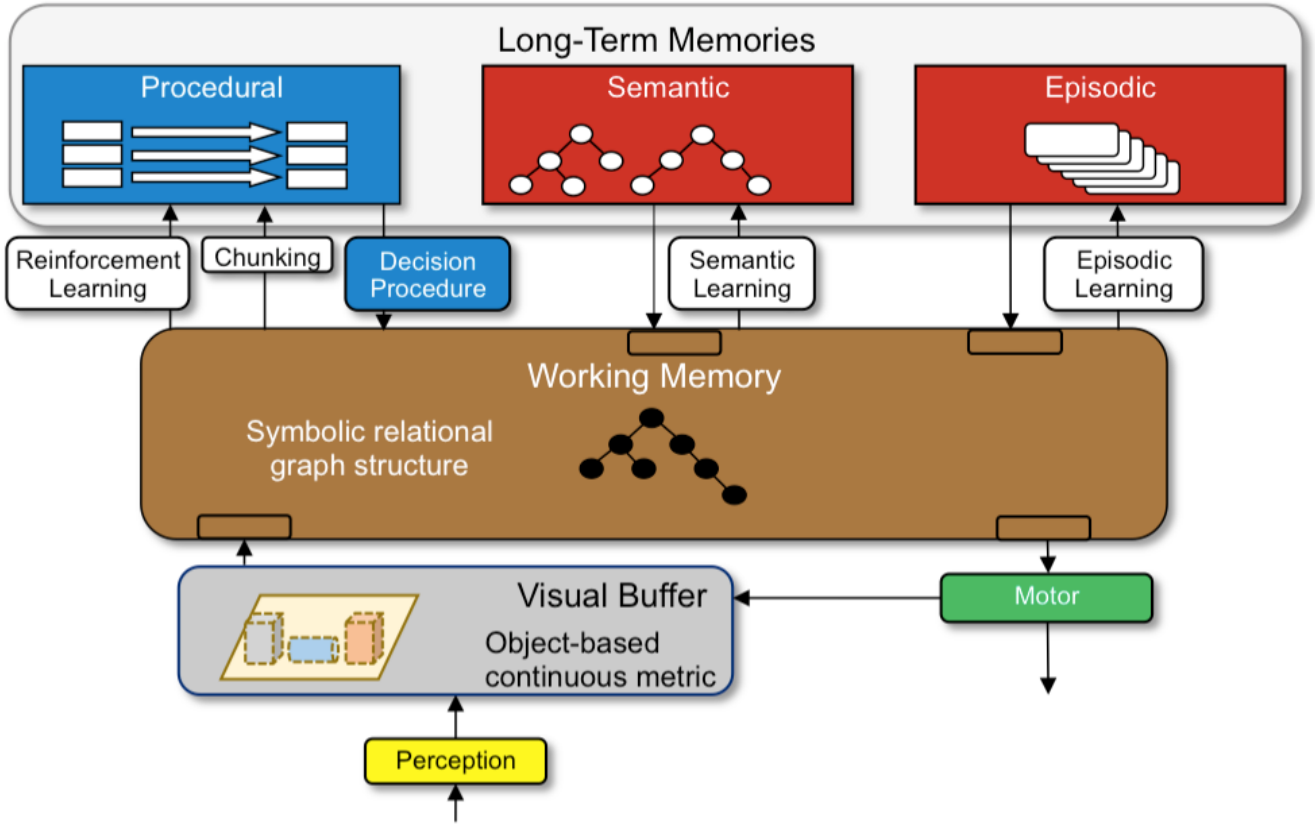


A Common Model of Cognition



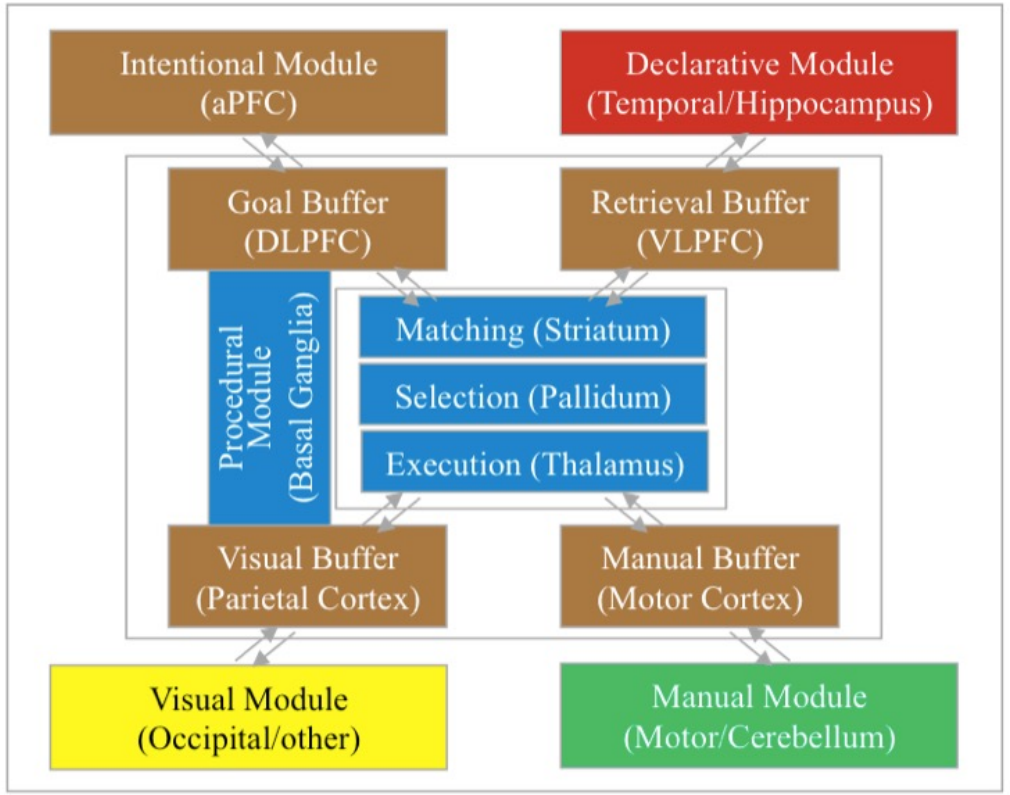
Soar

(Laird 2012)



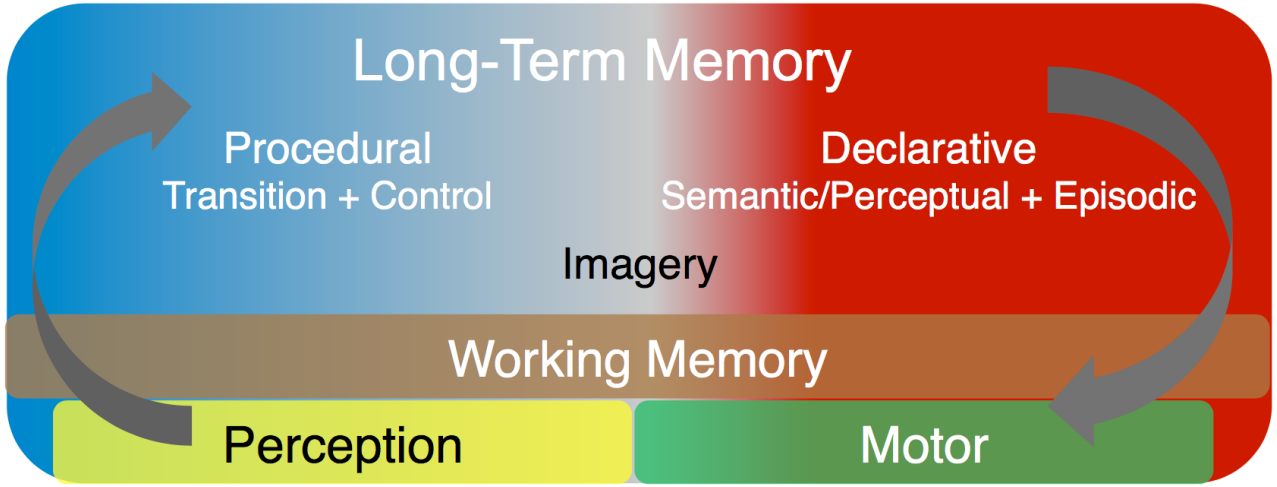
ACT-R

(Anderson 1990)



SIGMA

(Rosenbloom, Demski, and Ustun 2016)



A Common Model of Cognition

- cf. Standard Model in particle physics:
- For human-like minds
  - cumulative reference point … combines what is known
  - focus efforts to extend or revise
  - Not intended to be complete theory / model / implementation
  - Omissions: statement that a consensus is needed

A Common Model of Cognition

Hypothesis

"Cognitive architectures provide the appropriate computational abstraction for defining a standard model"

Standard model is not itself a cognitive architecture

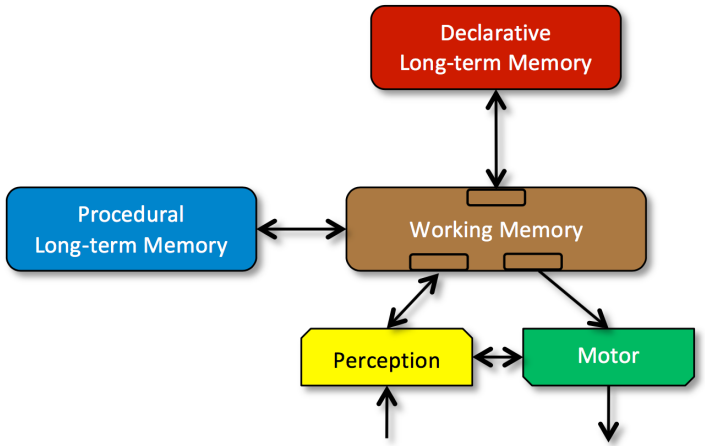
A Common Model of Cognition

- Evaluate single components
- Evaluate combinations of components
- Make components openly available to the research community
- Facilitate standard tests / testbeds

A Common Model of Cognition

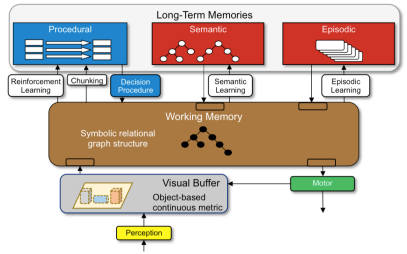
Key aspects

- Structure and processing
- Memory and content
- Learning
- Perception
- Motor (action)



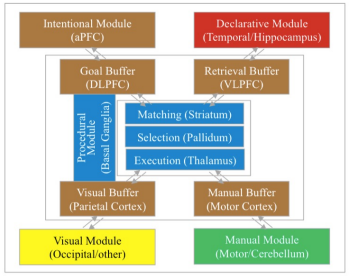
Structure and Processing

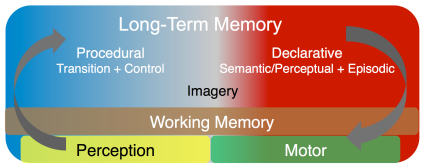
Cognitive Cycle – select a single deliberative act



Driven by procedural memory

- Tests the contents of working memory
- Selects an action that modifies working memory, leading to
  - Further actions (retrieved from procedural memory)
  - Initiate operations in other modules
    - Motor action
    - Memory retrieval
    - Perceptual acquisition
- Results go back in working memory

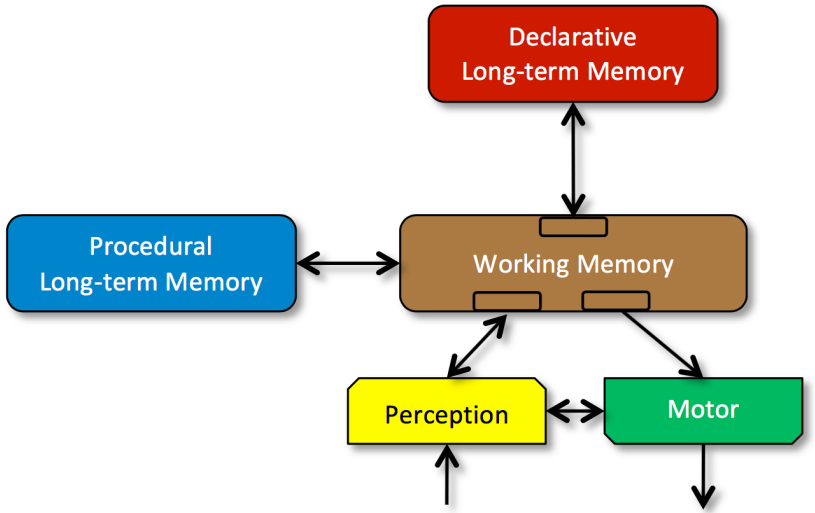




Complex behaviour: a sequence of cycles

Structure and Processing

"The existence of a cognitive cycle, along with an appropriate procedural memory to drive it, has become **definitional** for a cognitive architecture"



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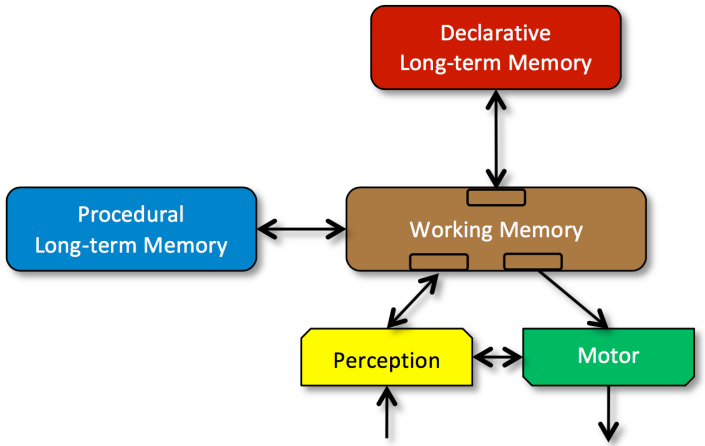
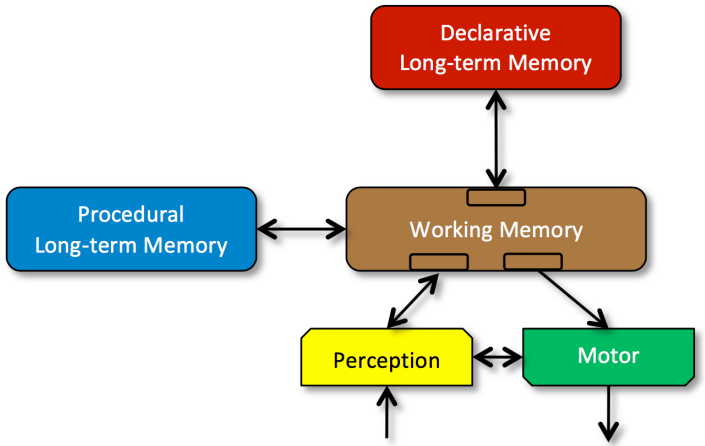


Memory and Content

- Memory components store, maintain, and retrieve content
- Content is represented as relations over symbols
- Quantitative metadata annotate instances of symbols and relations, modulating
  - Decision making
  - Storage, retrieval, learning of symbols and relations



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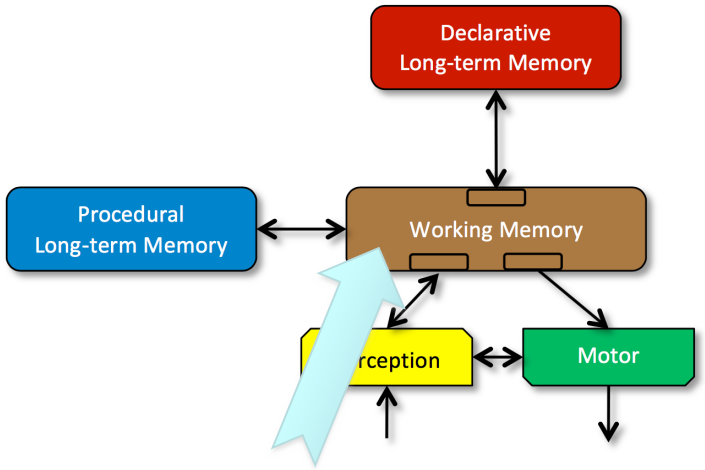

Temporary global space

Symbol structures are dynamically composed from perception and long-term memories

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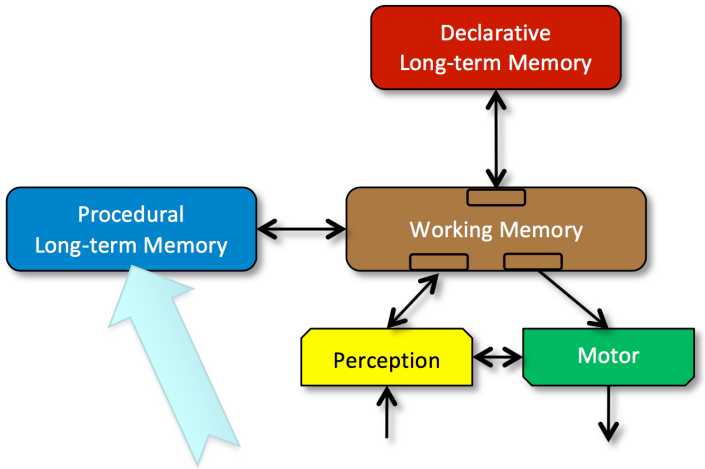

Knowledge about actions

Pattern-directed invocation:

Rules with conditions & actions

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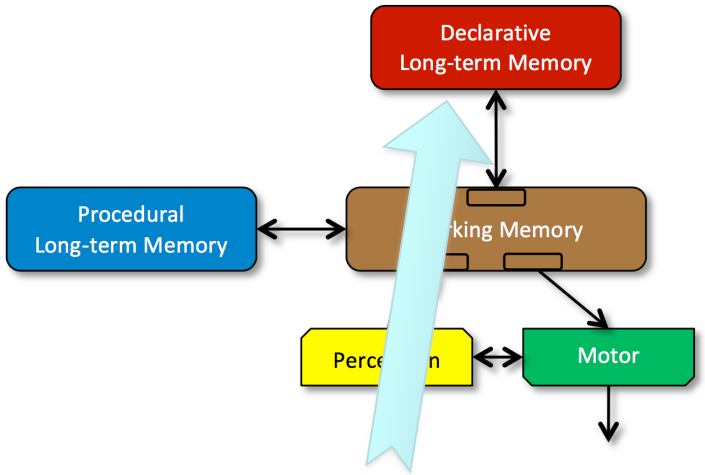

Facts and concepts

Structured as a persistent graph of symbolic relations +

Metadata (recency, frequency of co-occurrence, ...)

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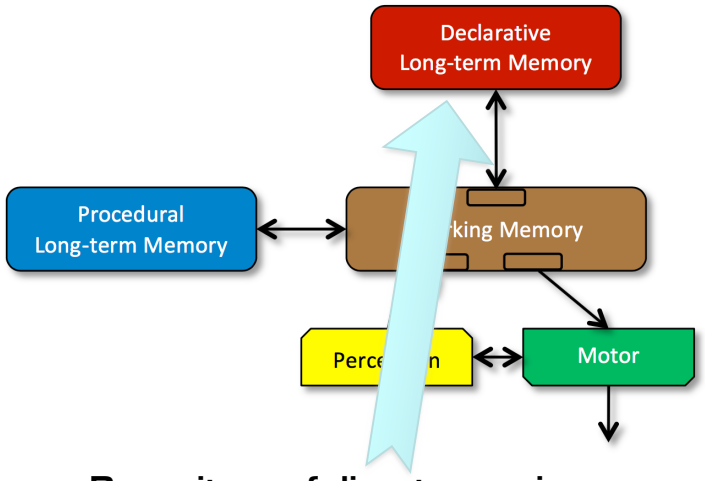

Repository of direct experience

"Not yet consensus concerning whether there is a single uniform declarative memory or whether there are two memories, one semantic and the other episodic"

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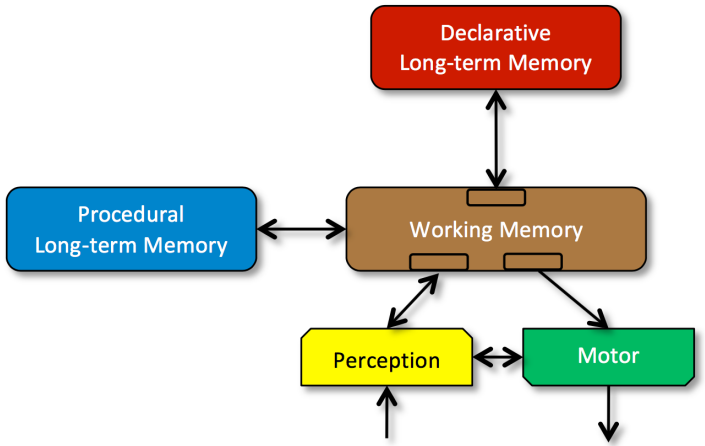
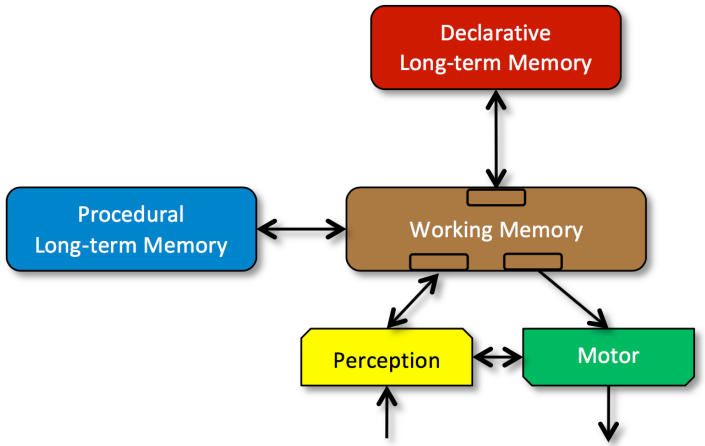


Learning

- Automatic creation of new symbol structures & tuning of metadata
- In long-term memory
  - procedural
  - declarative
- All types of long-term knowledge are learnable
- All learning is incremental
  - Based on experiences



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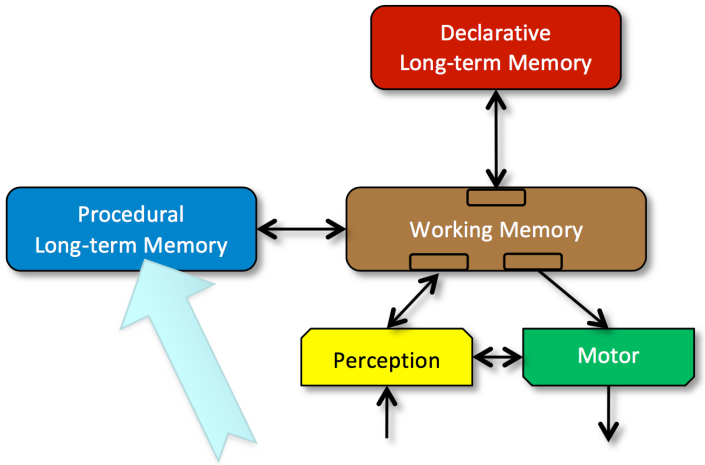

Two independent mechanisms

1. Create new rules from composition of rule firings
2. Tune selection between competing deliberate acts by reinforcement learning

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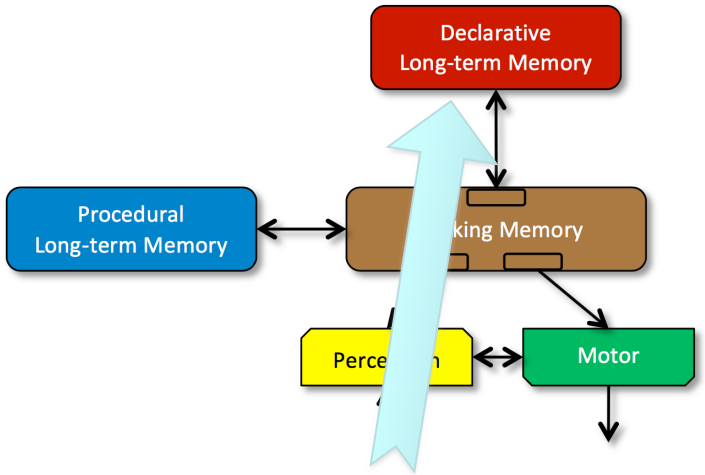

Two independent mechanisms

1. Create new relations
2. Tune associated metadata

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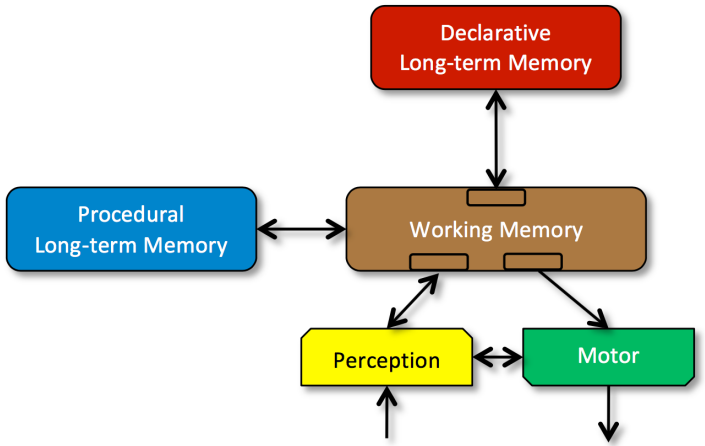
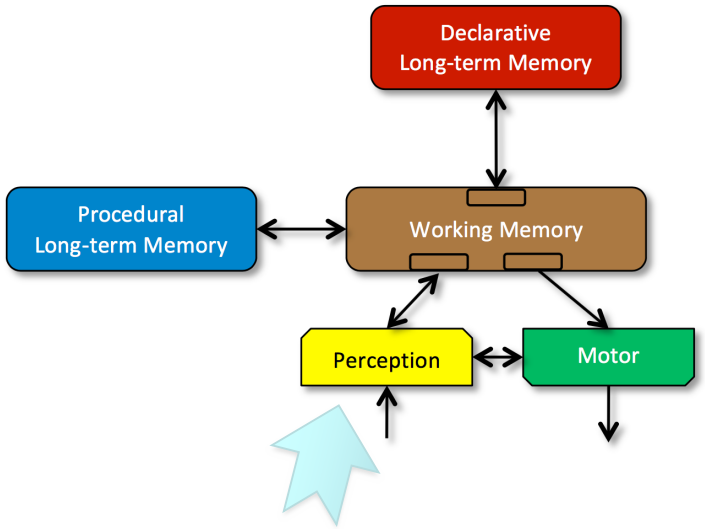


Perception

- Converts external signals into symbols and relations + metadata
- Places results in working memory
- Different modality sub-modules
  - Vision, Audition, …
- Standard model assumes an attentional bottleneck
  - Constrains the amount of information that can be placed in working memory



Working memory can influence perceptual classification and learning

A Common Model of Cognition

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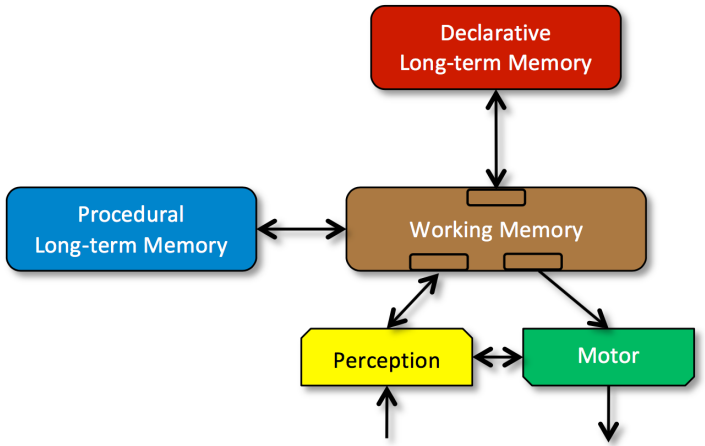
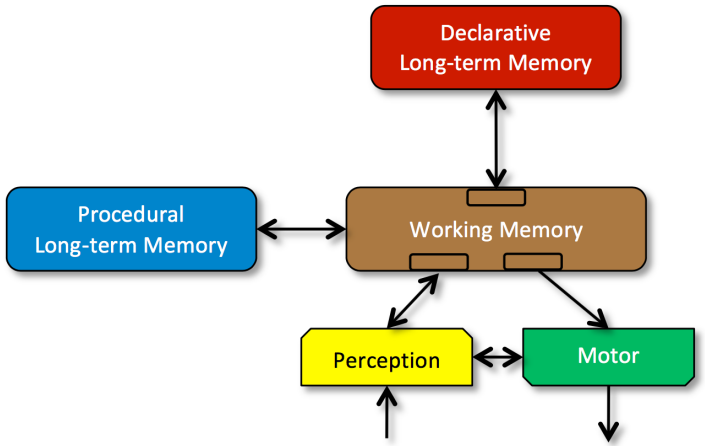


Motor

- Converts the symbol structures & metadata into external action
- Controlling body effectors
- "No consensus as the the form this should take in the standard model"



A Common Model of Cognition

"The standard model ... remains incomplete ...
[and] is silent, for example, concerning
metacognition,
emotion,
mental imagery,
direct communication and learning across modules,
the distinction between semantic and episodic memory,
and mechanisms necessary for social cognition"

Key Assumption

"A key foundational hypothesis in artificial intelligence is that minds are computational entities of a special sort

– that is, cognitive systems –

that can be implemented via a diversity of physical devices

a concept lately reframed substrate independence, Bostrom 2003".

Reading

Rosenbloom, P. S., Laird, J. E., and Lebiere, C. Précis of a 'Standard Model of the Mind', Advances in Cognitive Systems, Vol. 5, pp. 1-4, 2017.

Further Reading

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, 2017.

Stocco, A., Laird, J., Lebiere, C., and Rosenbloom, R. Empirical evidence from neuroimaging data for a standard model of the mind. In: Kalish, C., Rau, M., Zhou, J., Rogers, T. T. (eds) Proceedings of the 40th Annual Meeting of the Cognitive Science Society, pp. 1094–1099, 2018.