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SESAME & SOAR: A COMPARISON

SESAME OVERVIEW

- SESAME is a theory of human cognition
  - Stephan Kaplan (University of Michigan)
  - Modeled at the connectionist level
  - Mostly theory, not implementation
  - Basis in perception
  - Associative (Hebbian) learning used to explain a lot
  - Inspired more by animal and neural studies
    - Soar and ACT-R inspired more by human behavior
  - Emphasis on cortical areas of brain
    - Not basal ganglia, hippocampus, etc.

MOTIVATION

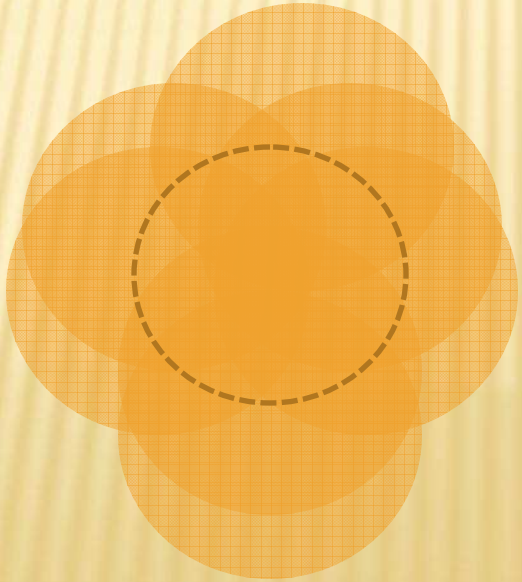
- SESAME has some striking similarities to Soar, which may provide insight into the basis of those aspects
  - Neural basis of rules, persistence, etc.
- Different emphasis that should be complementary to Soar's approach
- May provide a useful perspective on lots of things Soar is exploring these days
  - Working memory activation, clustering, sequencing, semantic memory, episodic memory, reinforcement learning, visual imagery

OUTLINE

- For each topic:
  - Describe topic from SESAME's perspective
  - Compare to Soar
  - Give possible inspiration/insight/lesson for Soar
- Topics:
  - Cell Assemblies (Symbols)
  - Memory (LTM and WM)
  - Activation
  - Persistence
  - Learning
  - Sequences
  - Episodic vs Semantic Memory
  - Metacognition
  - "Magic" of Human Cognition
  - Summary

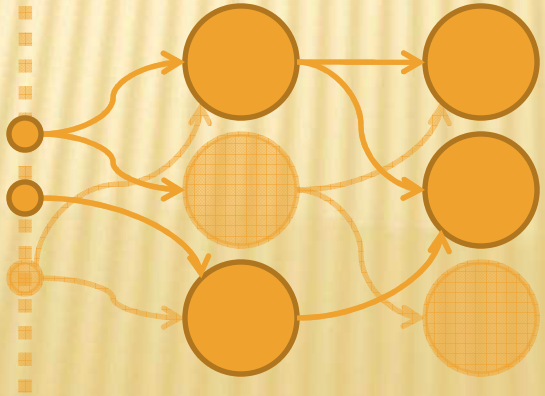
CELL ASSEMBLIES

- How does the brain recognize an object in different situations?
  - Some (random) neurons fire in response to specific features (e.g. color, size, texture, etc)
  - Neurons that fire together wire together
  - After many experiences, a group of neurons representing common features for an object become associated as a unit called the cell assembly (CA)



CELL ASSEMBLIES

- Cell assemblies are
  - Grounded in perception
  - Categories
  - Concepts
  - Prototypes
  - Symbols (but not in the full Newellian sense)
- Abstraction & Hierarchy: CAs at one level serve as features for the next level of CAs



COMPARISON: SYMBOLS

SESAME

- Symbols are CAs
- CAs are not fully Newellian
- CAs are grounded in perception
- CAs are categories, concepts, prototypes

SOAR

- Symbols are abstract basic unit
- Symbols are fully Newellian
- Symbols can be grounded in perception
- Symbolic structures are categories and concepts, and can be prototypes

Insight: Where symbols come from, properties of symbols

MEMORY

- CA structures are long-term memories
- Working memory is the set of active CAs
  - Activation is in-place (no retrievals or buffers)
- Limited Working Memory Capacity
  - Regional Inhibition: When CAs activate, they interfere with other nearby CAs
    - CAs compete in winner-take-all fashion to become the active representation for object/thought
  - Limits possible number of active CAs (WM capacity)
    - Roughly 5±2 for familiar CAs, which tend to be more compact

COMPARISON: MEMORY

SESAME

- LTM is network of all CAs
- WM is set of active CAs
  - Uses existing structure
- WM is limited

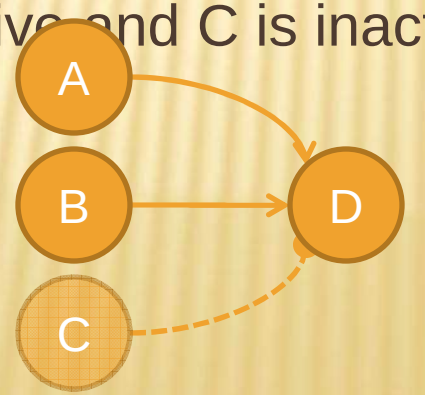
SOAR

- LTM includes Production Memory, Semantic Memory, Episodic Memory
- WM is set of elements created or retrieved from LTM
  - Creates new structure
- WM is not limited

Insight: Same structure for LTM and WM, WM limitations

ACTIVATION

- Activity of a CA is dependent on factors including:
  - Connections from other active CAs
    - Incoming connections may be excitatory or (locally) inhibitory
    - Required set of active/inactive connections may be complex
  - Reverberation: Positive feedback allows CA to remain active beyond incoming activity
  - Fatigue: As CA remains active, threshold for activation increases
- May be able to describe spread of activation among CAs in rule form:
  - If A and B are active and C is inactive, then D activates.



COMPARISON: ACTIVATION

SESAME

- Activation spreads based on rule-like learned connections
- Activation impacted by incoming connections, reverberation, inhibition, fatigue
- Spread of activation and CA activation are same thing

SOAR

- Symbol creation propagates via elaboration rules
- Activation based on activation of symbols that cause rule match, boost from usage, and decay
- Symbol creation and activation are different things

Lesson: Neurologically-accurate WM activation model

PERSISTENCE (CONTROL)

- May need to keep a CA around for a while (e.g. to work on a problem)
- Other “distraction” CAs can interfere
- Inhibitory attention blankets all CAs in (global) inhibition
  - Highly active CAs are impervious to effect
  - Weaker distractions are inhibited

SESAME

- Persistence achieved via inhibitory attention
  - Prevents activation of distractor CAs

SOAR

- Persistence achieved via operator selection and application
  - Selection of an operator inhibits selection of other operators (and creation of associated symbols)

Insight: None really – Soar already uses inhibitory mechanism

COMPARISON: PERSISTENCE (CONTROL)

LEARNING

- Associative (Hebbian)
  - Learns associations between CAs that are often active concurrently (CAs that fire together wire together)
    - Includes sequentially active CAs, since CAs reverberate
  - Learns lack of association between CAs that are not commonly active concurrently
    - Results in (local) inhibitory connections
  - Learning rate is typically slow, but high arousal causes fast learning

COMPARISON: LEARNING

SESAME

- All learning is associative (doesn't really cover RL)
- Learning is typically slow (but modulated by arousal)

SOAR

- Many types of learning
  - Chunking
  - Semantic
  - Episodic
  - Reinforcement
- Chunking, semantic and episodic are fast, reinforcement is typically slow (but modulated by learning rate)

Insight: Proliferation of learning types in Soar results from proliferation of memory types, role of arousal in learning

SEQUENCES

- Sequences are stored in cognitive maps
- Cognitive maps are “landmark”-based maps of problem spaces
  - Nodes are CAs
  - Connections represent CAs that have been experienced in sequence
  - Since experienced sequences overlap, novel sequences are also represented (composability)
- Problem solving involves finding paths through cognitive maps
- Paths may be associated with “affective” codes that help guide the search
  - Codes learned via reinforcement learning

COMPARISON: SEQUENCES

SESAME

- Sequences stored in cognitive maps
- Can achieve limited composability
- Problem solving is searching through cognitive map (which represents problem space)
- RL helps improve search

SOAR

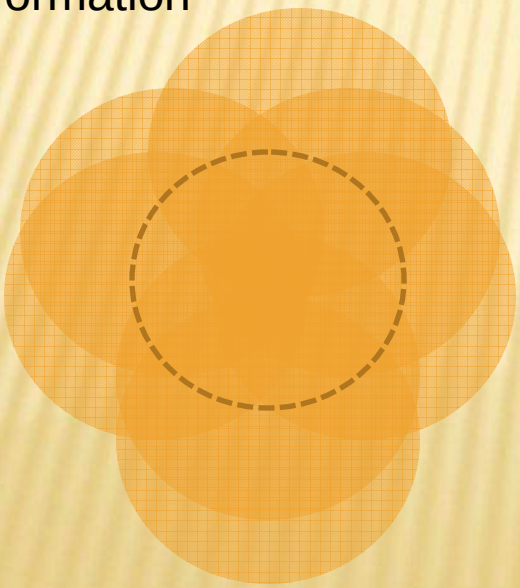
- Sequences can be stored in operator application rules or in declarative structures
- Can achieve arbitrary composability
- Problem solving is search through problem space
- RL helps improve search

Insight: Limited composability may be enough

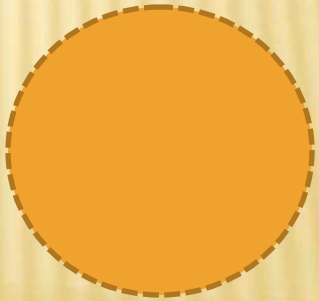
EPISODIC VS SEMANTIC

- CAs are typically derived from multiple overlapping experiences
  - Thus, tend to be semantic in nature
- A highly-arousing event may be strong enough to form its own CA
  - Thus, can have episodes

Semantic Memory Formation



Episodic Memory Formation



EPISODIC VS SEMANTIC

- In general, there is no clear distinction between semantic and episodic memories
  - CAs include full spectrum between episodic and semantic
  - Each time a CA is active, can be modified (allows for episodic memory modification)
- Hippocampus thought to play a role in contextualizing episodic memories, but not in storage

COMPARISON: EPISODIC VS SEMANTIC

SESAME

- No clear distinction
  - CAs encode both kinds of memories with a smooth transition
- Story on role of hippocampus is not completely worked out
  - Memories are not stored in hippocampus

SOAR

- Episodic and semantic memories are learned, stored and retrieved separately
- Episodes are assumed to be initially stored in hippocampus before migrating to cortex

Insight: May not need separate episodic and semantic memories

METACOGNITION

- Brain monitors CA activity to determine current state
  - Focused, high levels of activation: Clarity
  - Diffuse, lower levels of activation: Confusion
- Serves as signals about how processing is going
  - Provides opportunity to change processing
- Clarity/Confusion experienced as pleasure/pain
  - Can influence learning

COMPARISON: METACOGNITION

SESAME

- Clarity/Confusion signal how things are going
- Influence learning via pleasure/pain signals
- Details are sketchy

SOAR

- Impasses arise when processing cannot proceed
- Allows for learning via chunking

Lesson: None really – impasses provide same functionality

MAGIC OF HUMAN COGNITION

- Special mechanisms
  - Human perceptual mechanisms are different than other animals
  - Leads to different features that CAs learn over
- Quantitative differences
  - Many animals have CAs and association mechanisms, but the larger quantity in humans may lead to qualitative differences
- In other words: There is no single mechanism that gets us the “magic” -- interaction of all pieces is necessary

COMPARISON: MAGIC OF HUMAN COGNITION

SESAME

- Everything is necessary

SOAR

- Everything is necessary

Laird's lesson: "There is no magic, just hard work"

HIGHLIGHTS: WHAT SOAR CAN LEARN FROM SESAME

- SESAME ideas can provide grounding and inspiration for extensions to Soar
  - Associative learning can get you:
    - Non-arbitrary symbols via clustering-type mechanism
    - Sequences
  - Working memory
    - Soar's activation model could account for more features
      - Reverberation
      - Fatigue
      - Inhibition (local, regional, and global)
    - Basis for limited capacity
  - Arbitrary composability may not be necessary
  - The role of arousal in learning
  - Episodic/Semantic memories may not be as distinct as they are in Soar