Modeling Aspects of Human Memory and Reasoning For Scientific Study (08-1155)

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Problem

- To date, computational models have not neuro-cognitively represented episodic recollection and memory within an embodied, simulation environment.
- This creates several limitations regarding the plausibility of current models.
  - Current approaches do not dynamically collect "what," "where," and "when" visual information to produce an episodic memory trace.
  - Current approaches often create a false distinction between semantic and event-based, episodic memory. While semantic memory has a different phenomenology than episodic memory, there is strong evidence they are part of the same system (McKoon et al., 1986).

Approach

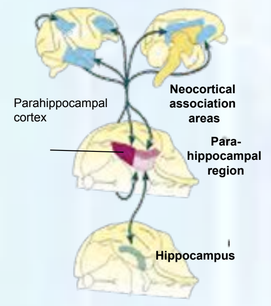
- Develop a computational system that exhibits processes and behaviors of humanly plausible retrospective memory and recall.
- Represent how knowledge is organized and updated through information from individual experiences (episodes) via the cortical-hippocampal memory system — leading to the consolidation of long-term, declarative memories.
- Empirically test behavior of cognitive representations against human behavior.

There is a general consensus that the cortex is the repository of detailed representations of perceptions and thoughts and that the hippocampus supports the ability to bind together cortical representations and, when cued by part of a previous representation, to reactivate the full set of cortical representations that compose a recollective memory.

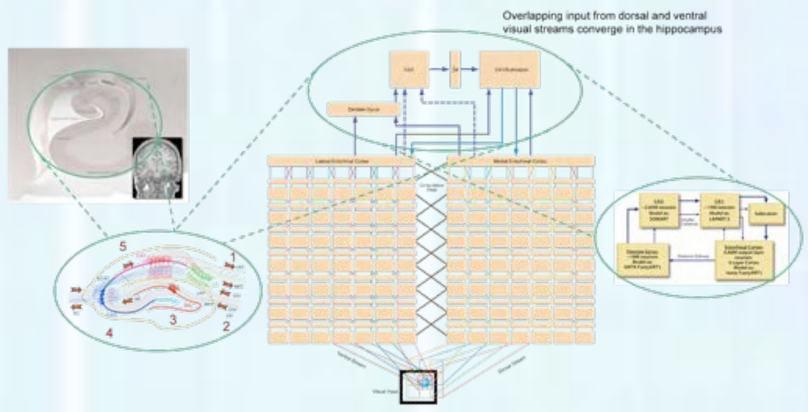
Two Complementary Sub-systems

1. **Cortex**—Slower, higher fidelity memory
2. **Hippocampal System**—Quicker, rough-estimate memory

- Cortical-Hippocampal System represents and stores declarative memories for later recall.
- **The theory** is that certain information is first represented in the hippocampus, which is then consolidated into different cortical regions of the brain for long-term storage



Suzuki & Amaral, 1994; Burwell & Amaral, 1998

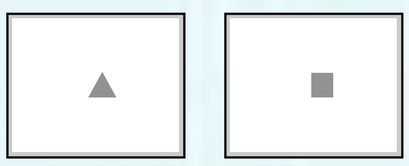


1. Neocortical Visual Processing – Is responsible for visual perception inputs ~66K FuzzyART modules
2. Entorhinal Cortex – Mechanism for the pre-processing (familiarity) of "what" input signals.
3. Dentate Gyrus – Distinguishes multiple instances of similar events or multiple visits to the same location – "where" information
4. CA3 – Assists in the temporal coding (i.e, "when" info) the memory representations
5. CA1 – Decodes the sequence signals back to the cortex and to compare predictions of the network for the next sequential item to actual information as it arrives

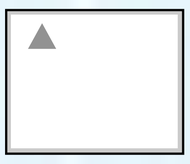
Results

- **Comparison Between Human Subjects and Computational Simulation Results**
  - The model was validated by comparison with data collected from human subjects several episodic memory studies.
  - Participants/Computer were showed several objects in a specific order and in specific positions.

Task 1: Co-Occurrence
Testing the recall of items presented together during training



Task 2: Sequential Relations
Testing the recall of items in the same order as they were during training

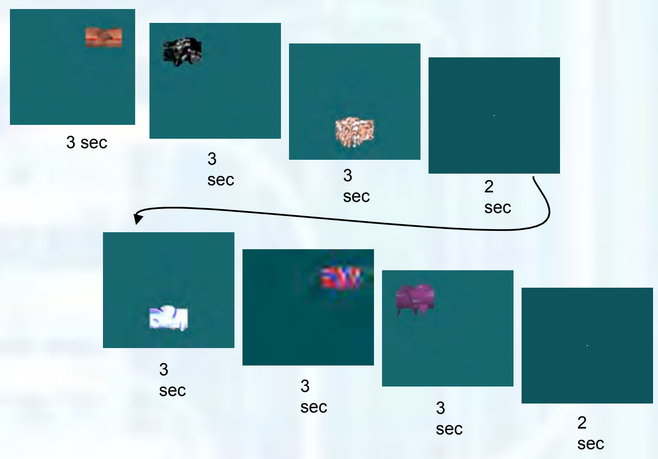


Task 3: Spatial Relations
Testing the recall of items in the same locations as they were during training

Sample geometric stimuli presented to the computer simulation

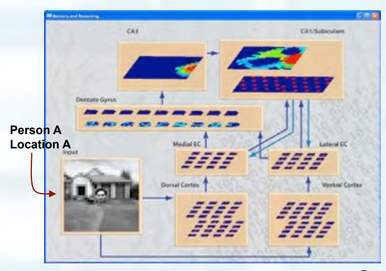
Results (cont.)

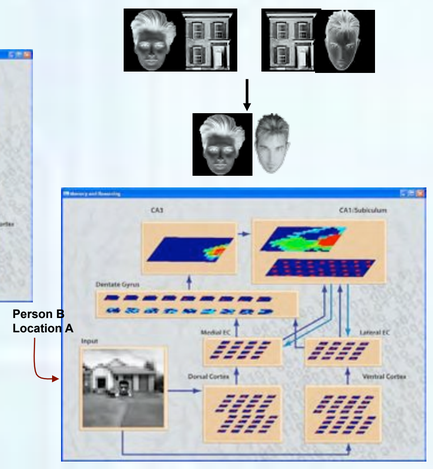
- **Comparison Between Human Subjects and Computational Simulation Results**
  - The Konkel et al. study presented subjects with sequences of novel visual stimuli, as shown below, and later tested their performance on co-occurrence, sequential relations, and spatial relations memory tasks.
  - Comparably, our model was presented orthogonal input stimuli corresponding to focus and context visual images. Activations in the various computational regions were then analyzed analogously to neural probing to determine model recognition.



Kinkel, A., Warren, D., Duff, M., Tranel, D., & Cohen, N. (2008). Hippocampal amnesia impairs all manner of relational memory.

- **Comparison Between Human Subjects and Computational Simulation Results**
  - The Preston et al. studied co-occurrence memory association of objects within a particular contex
  - Comparably, our model was presented a facial image within particular background (context).
  - Preston, Alison R. (2004). Hippocampal contribution to the novel use of relational information in declarative memory." Hippocampus, 148-52.





Co-occurrence of Persons A & B with location A causes CA1 activation overlap indicating a association of the persons with the location–as with humans

- **Computational Model Results**
  - General Assessment and Conclusion

"This model supports the ability to do classification/categorization of a range of visual inputs, to remember the prior occurrence of each of those inputs individually, to do pattern completion permitting recovery of those items based on partial or incomplete cues, to represent different locations in the visual environment, to remember which individual items occurred in which locations, and to bind together in memory representations of any arbitrary collection of items with one another and with their spatial or other contexts. And all of these capabilities are implemented in a model with biological realism greater than in any previously implemented model. Finally, it is done in a way that permits us to test the contributions of each of the individual components of the model and to compare that with what is seen in humans and animals."
Neal Cohen, PhD.

Significance

University Collaborators

Declarative Memory

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