Modelling the effect of prioritisation in a visual working memory task

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Talk outline

- The ACT-R cognitive architecture
- Hitch et al. (2018)
- Model of Hitch et al. (2018), experiments 1 and 2

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- *Caveat*
  - ACT-R is a complex system
  - Based on a few relatively simple principles
  - Explanation focussed on relevance to the model

The ACT-R cognitive architecture

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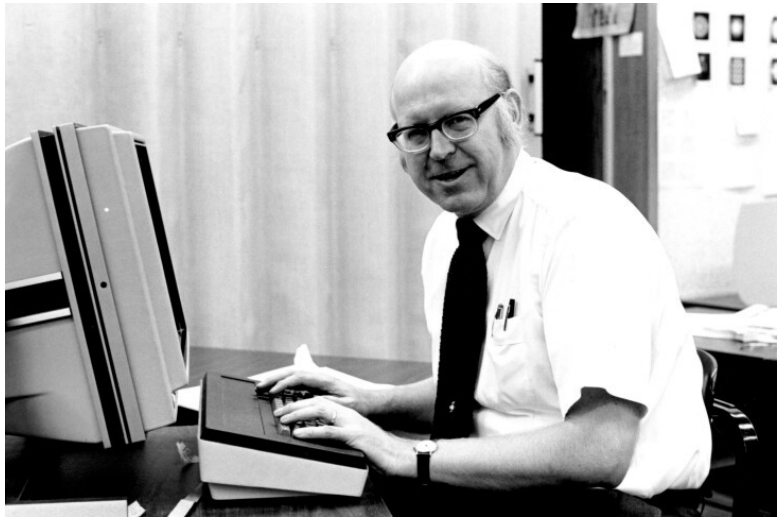
- Specify the core components of the mind and how they integrate to create intelligent behaviour

Playing 20 questions with nature

- Lack of integration and cohesion of theories and results (Newell, 1973)
- "Microtheories" are developed without being required to fit with other theories
- Newell (1990) argued for "unified theories of cognition" to integrate disparate results



Allen Newell

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- Soar (Laird, 2012; Laird et al., 1986; Newell, 1990)

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- Commercial applications
  - SoarTech (human simulation)
  - Carnegie Learning, MemoryLab (education)

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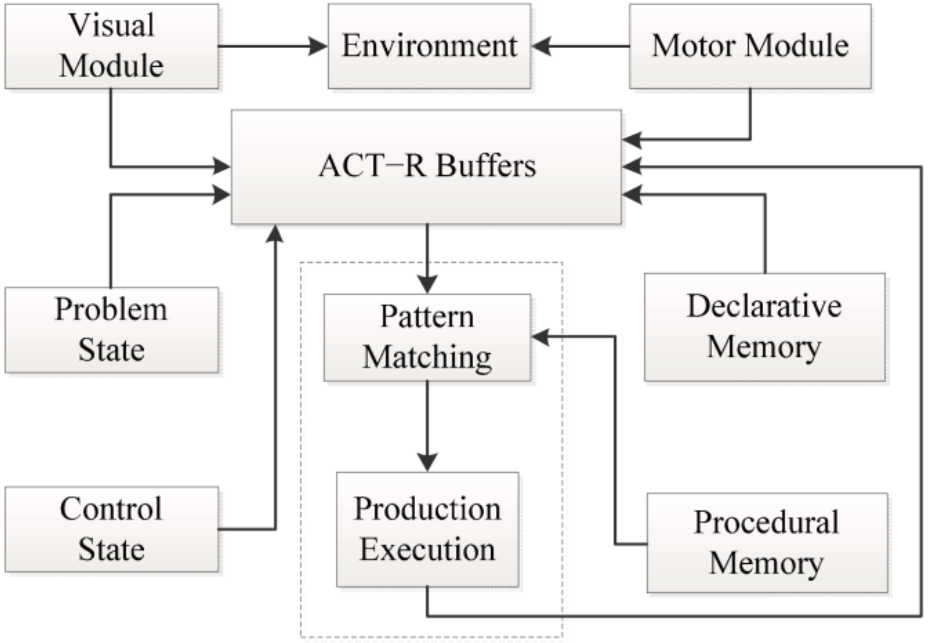
- Modules to simulate vision, audition, and motor action to interact with task environments

Key components of ACT-R



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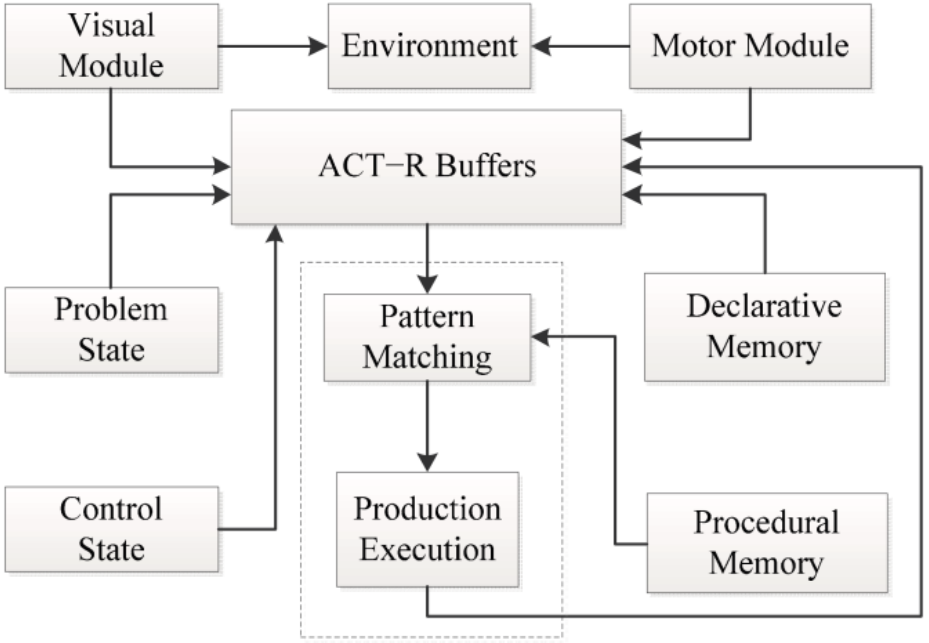

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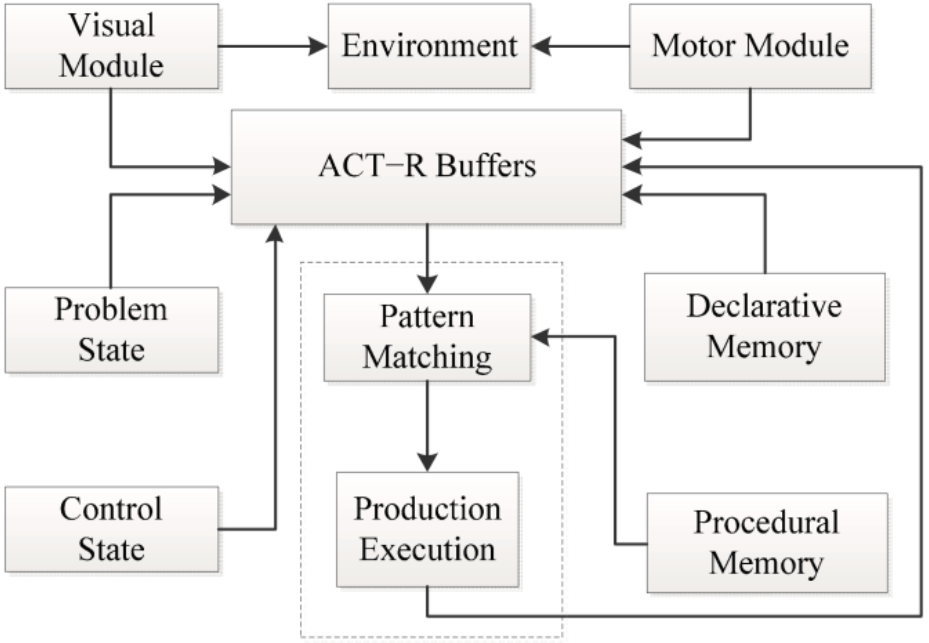

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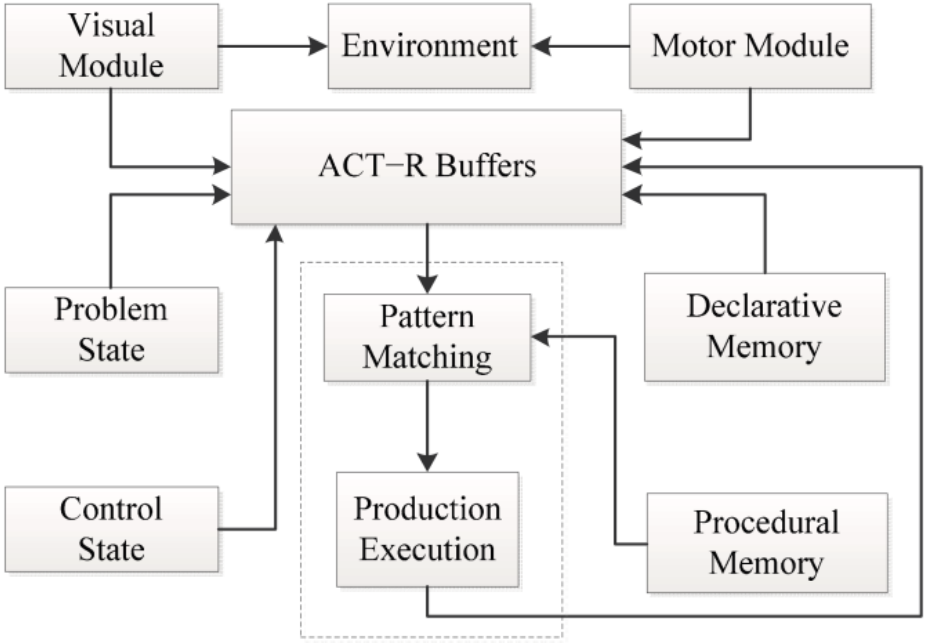
- Control state: "Goal" module/buffer keeps track of the current goal
- Problem state: "Imaginal" module/buffer for holding and manipulating current task-relevant information

Rule-based sequential behaviour



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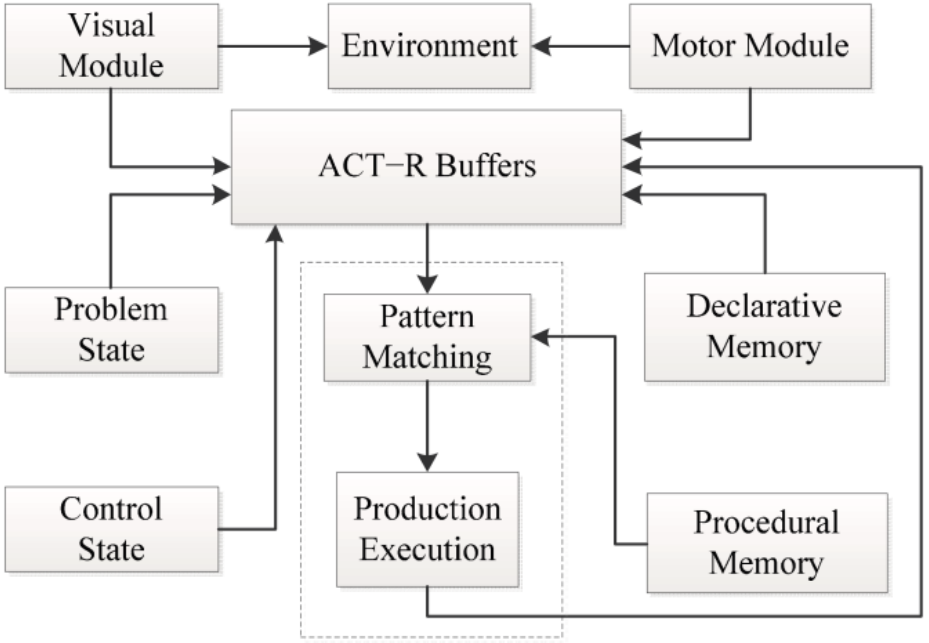

- Every 50ms, snapshot of all buffer contents (goal state, visual object, retrieved knowledge etc.) is taken
- Production rules matching buffer contents compete to "fire". Winner executes its actions (e.g., memory retrieval, motor actions, eye movements, update goal)

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- Chunks with cue[s] and activations above a retrieval threshold can be retrieved. Highest activated chunk wins
- Stochastic process, activations include noise component

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  - Chunks in declarative memory above retrieval threshold
- Imaginal buffer is a one-chunk working memory, representing the focus of attention (Borst et al., 2010; Nijboer et al., 2016)
- ACT-R's WM functions are domain-general
  - Operate on the medium of knowledge chunks

Focus of attention in visual working memory

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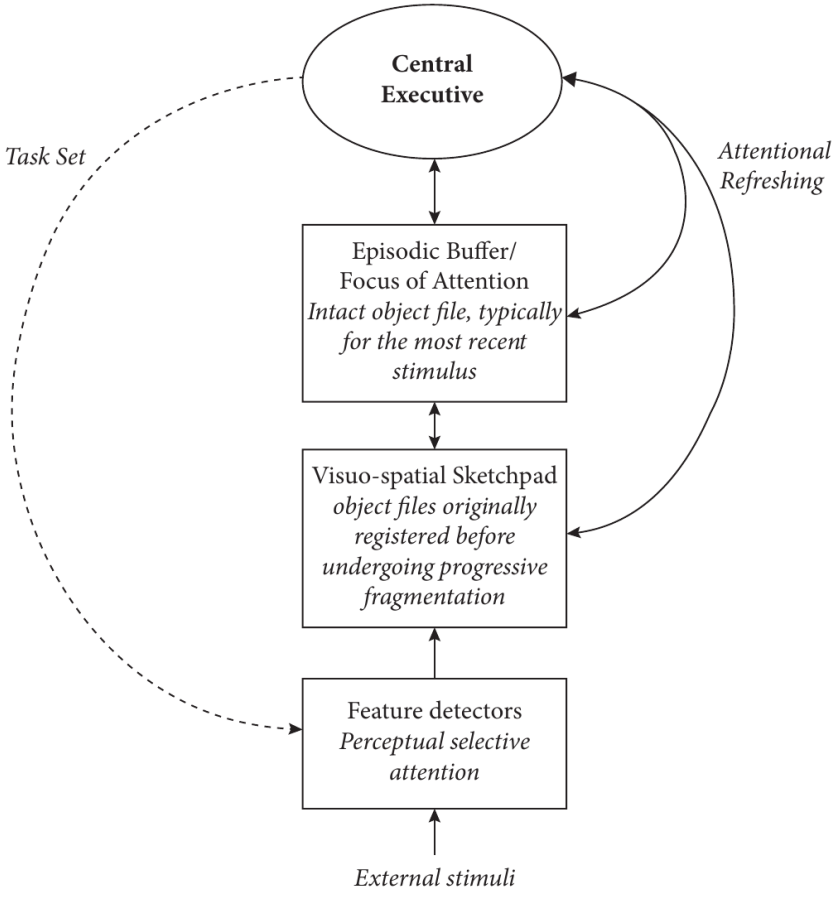
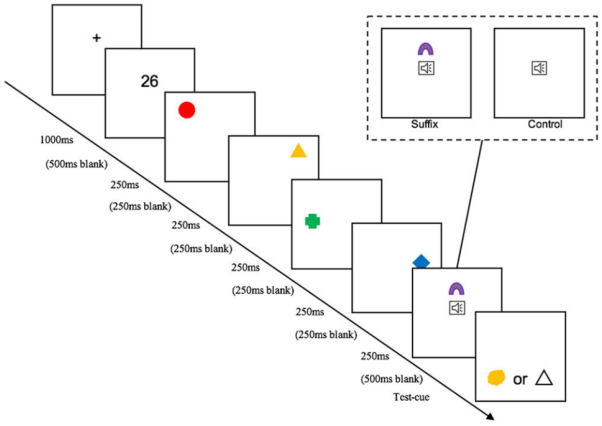
- Episodic buffer limited capacity (1 item) store (Baddeley, 2000)
- Contents determined by
  - Bottom-up perceptual processes
  - Top-down executive processes
- Attentional refreshing maintains items in episodic buffer

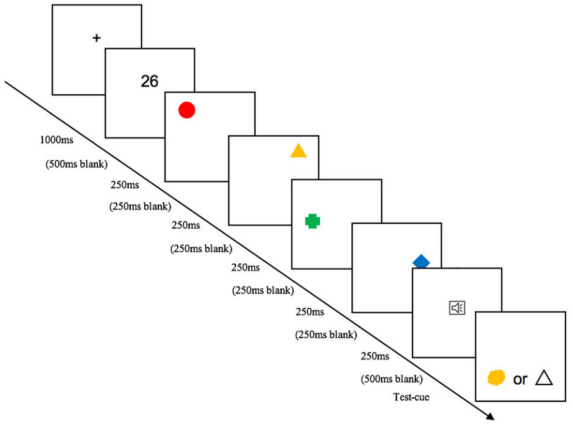


Visuo-spatial working memory (Baddeley et al., 2020)

Experiment designs



Exp 1 ($2 \times 2 \times 4$)

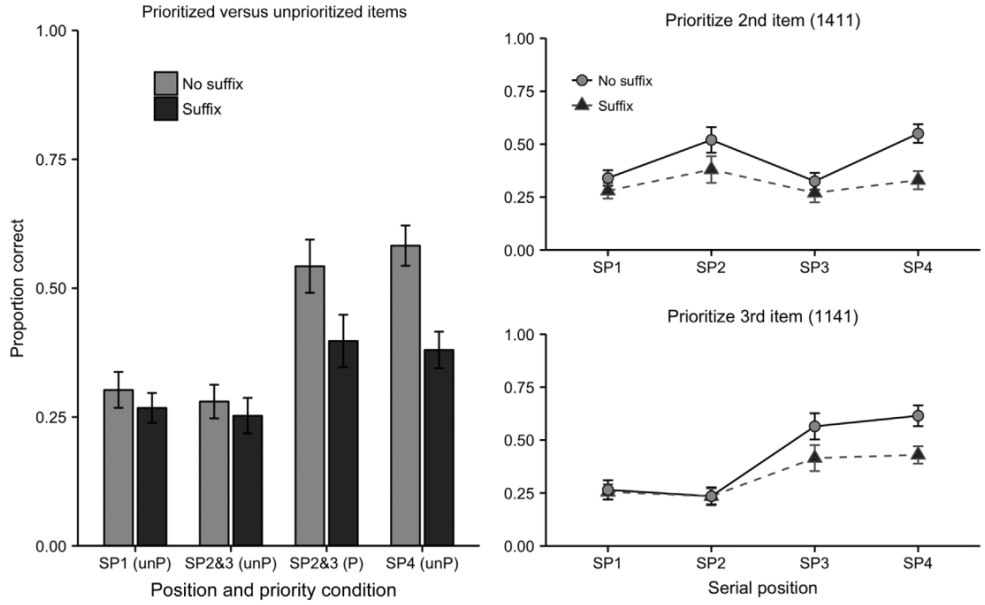


Exp 2 (4×4)

- Prioritisation and suffix
- 1 Priority (2 | 3)
- 2 Cue SP (1 | 2 | 3 | 4)
- 3 Suffix | No suffix

- Prioritisation on recency
- 1 Priority (0 | 1 | 2 | 1 & 2)
- 2 Cue SP (1 | 2 | 3 | 4)
- No suffix

Experiment 1 results



- Prioritisation of SP2 and SP3 increased recall
  - Increase reduced by suffix (significant only for SP3)
- Recency effect (SP4) found which was decreased by suffix
- Significant reduction in recency (SP4) when SP2 prioritised (compared with SP3)

Explanation of Experiment 1 results

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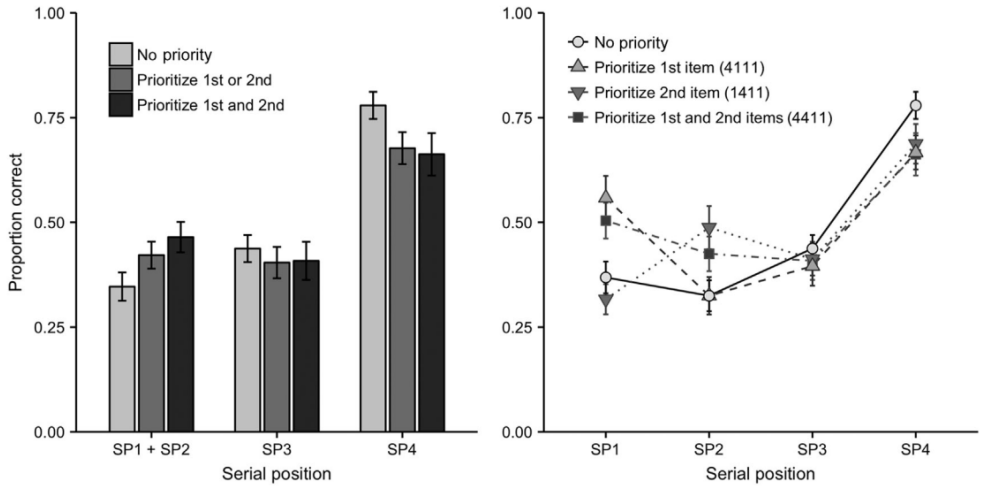
- Prioritised information competes with recently presented information (i.e., SP4 and suffix) to occupy FoA

Experiment 2 results



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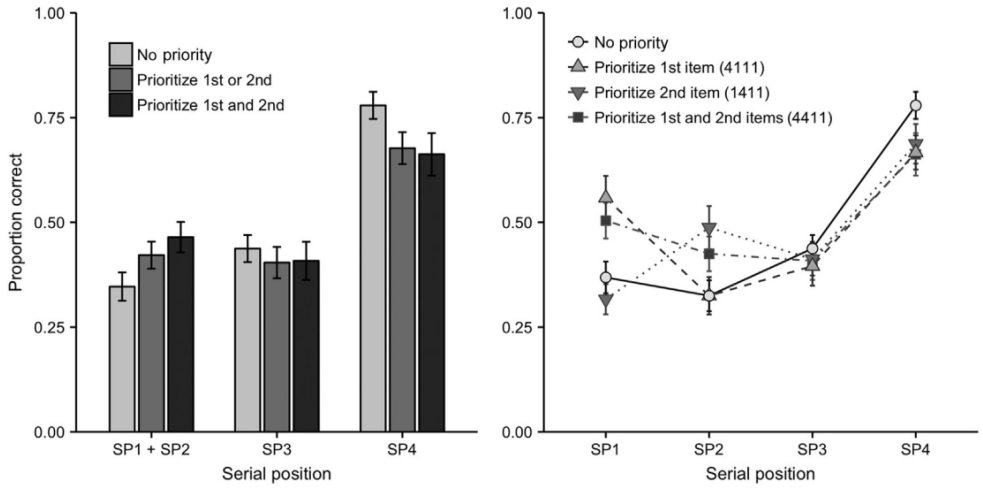

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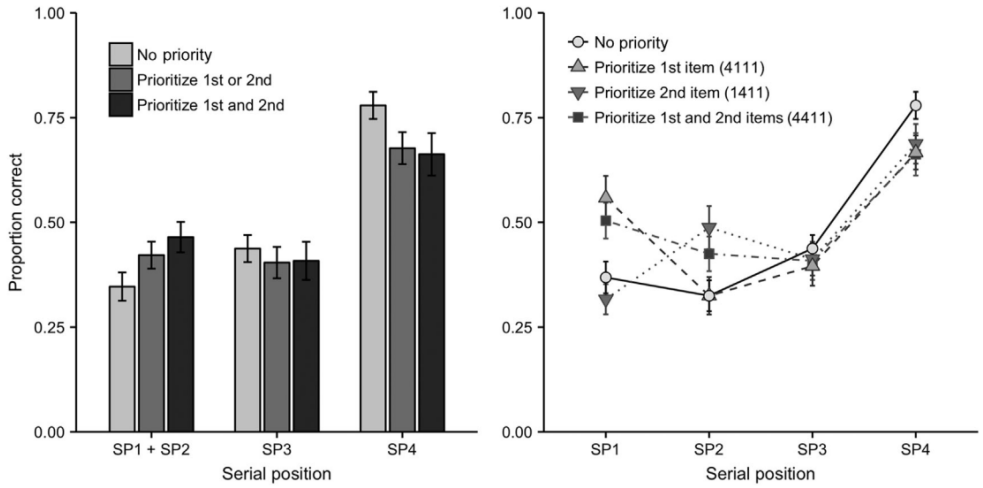

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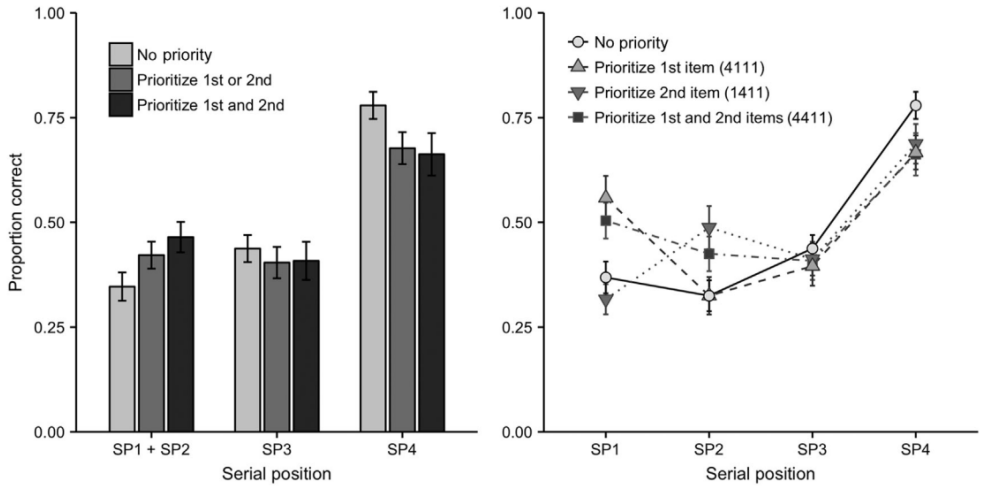

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- SP4 Recall sig higher in baseline condition than in three priority conditions

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- Reduction in recall for SP4 due the maintenance of SP1 and/or SP2 in FoA
- No sig diff between effects of prioritising single item versus two items
  - Attentional refreshing alternates between SP1 and SP2, moving them in turn into the episodic buffer (and the focus of attention)
  - Cost incurred – slight reduction in accuracy for both compared to individual prioritisation

General conclusions

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- "The boost due to prioritisation came at a cost that fell principally on memory for the most recent item, reflecting the limited capacity of the FoA"
- Experimental effects interpreted in terms of the probabilities of items occupying the FoA at test

Modelling the task in ACT-R

Aims of creating the model

- Can ACT-R account for the data within the constraints of its mechanisms and assumptions?
- How would ACT-R implement/explain
  - The mechanism by which study items are prioritised
    - How multiple items are prioritised
  - The effect of prioritisation on recency (SP4)
  - The effect of the suffix on prioritisation and recency

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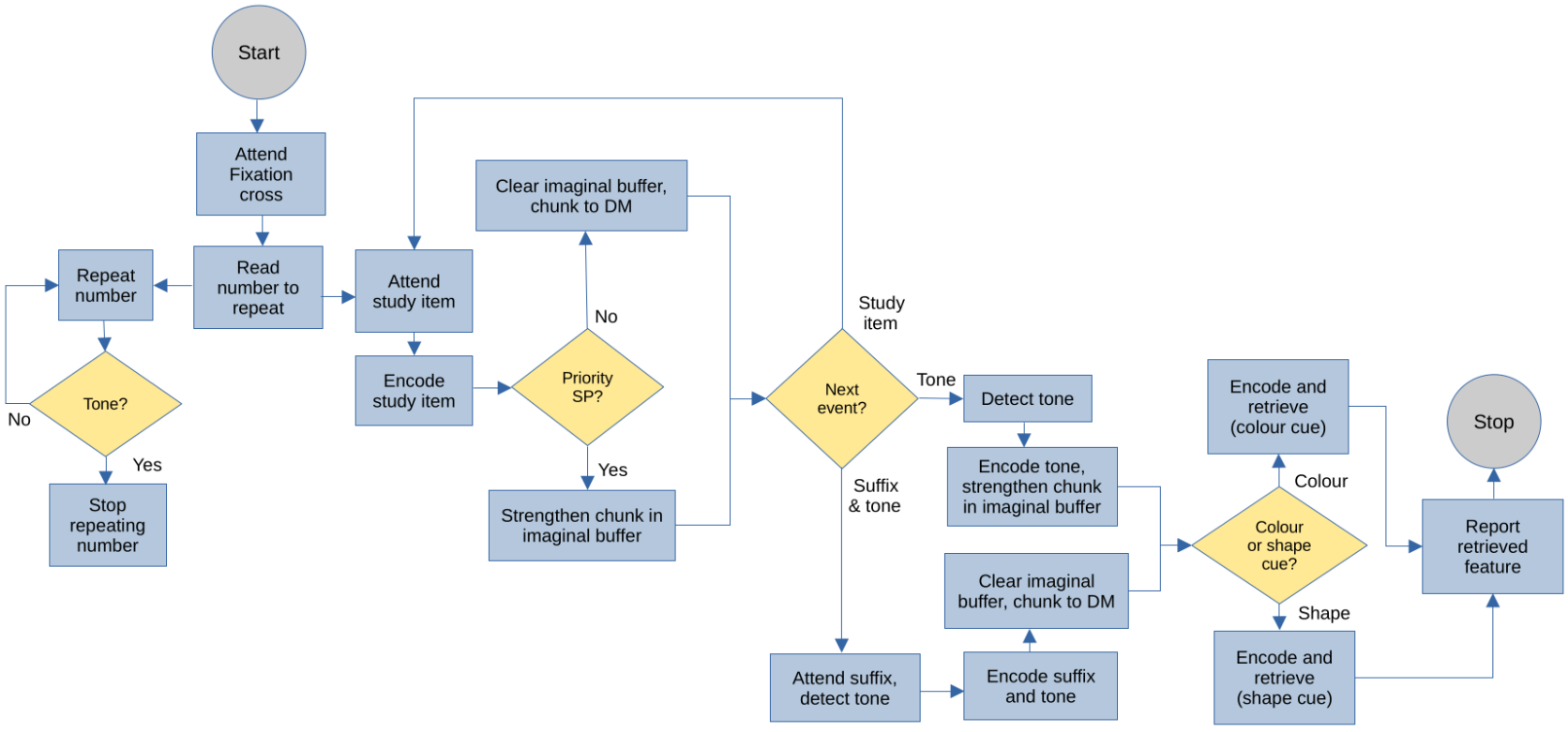
- Create production rules that implement the strategy
- Run model and compare with human data
- Adjust model's free parameters to optimise fit between human and model data

Control structure for one trial



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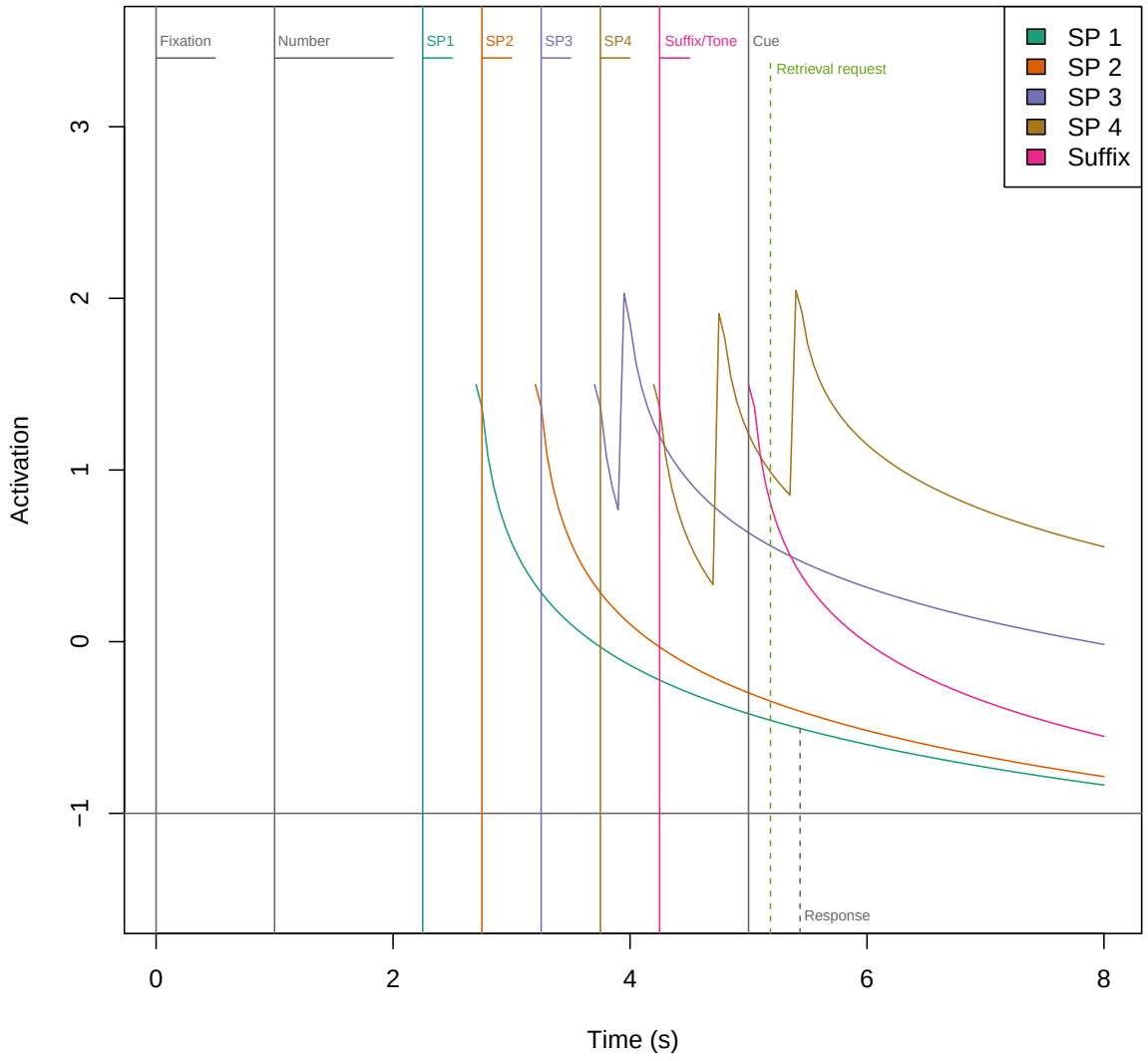
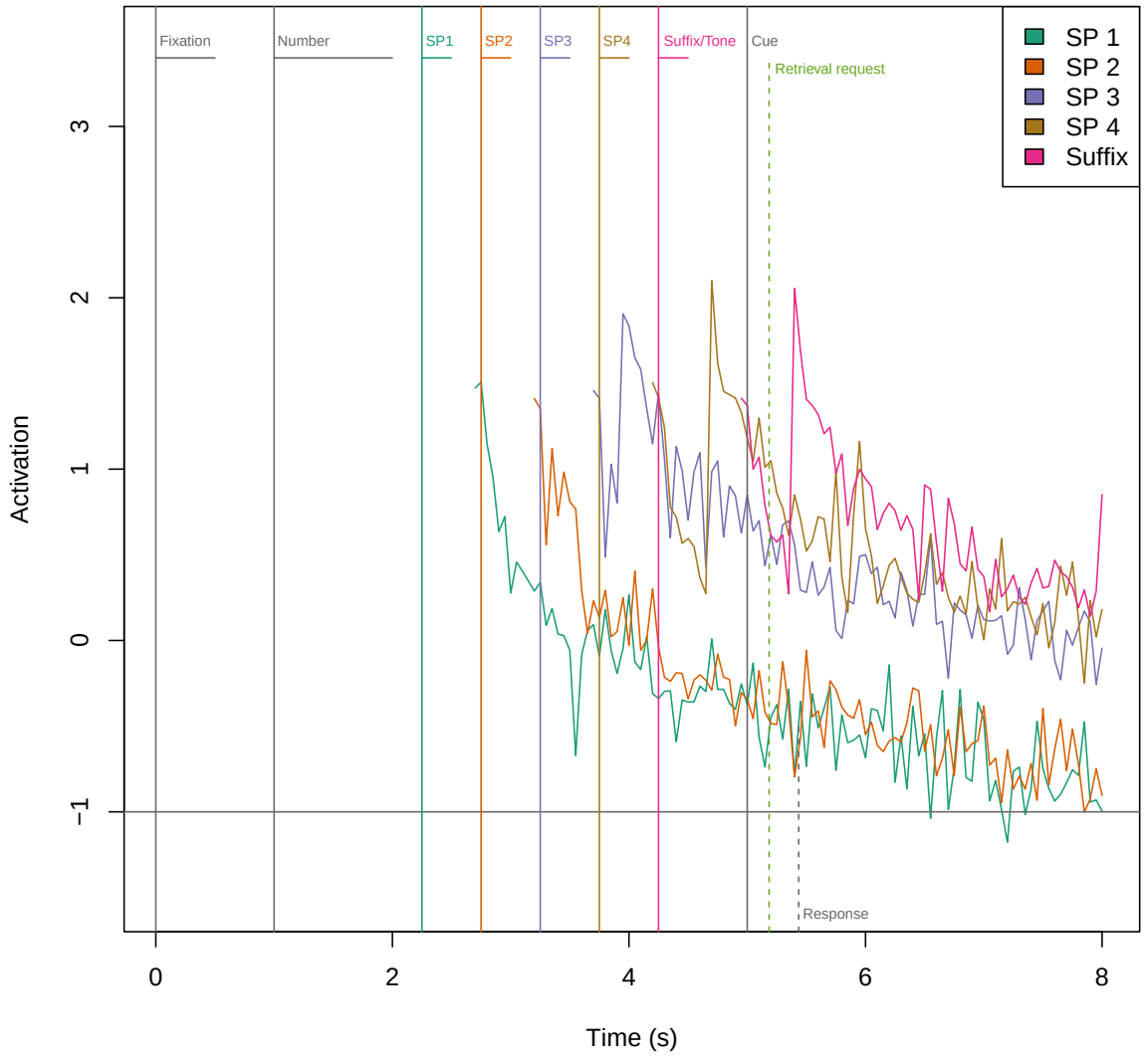
- Crucial difference
  - No competition for space in FoA during trial or at test

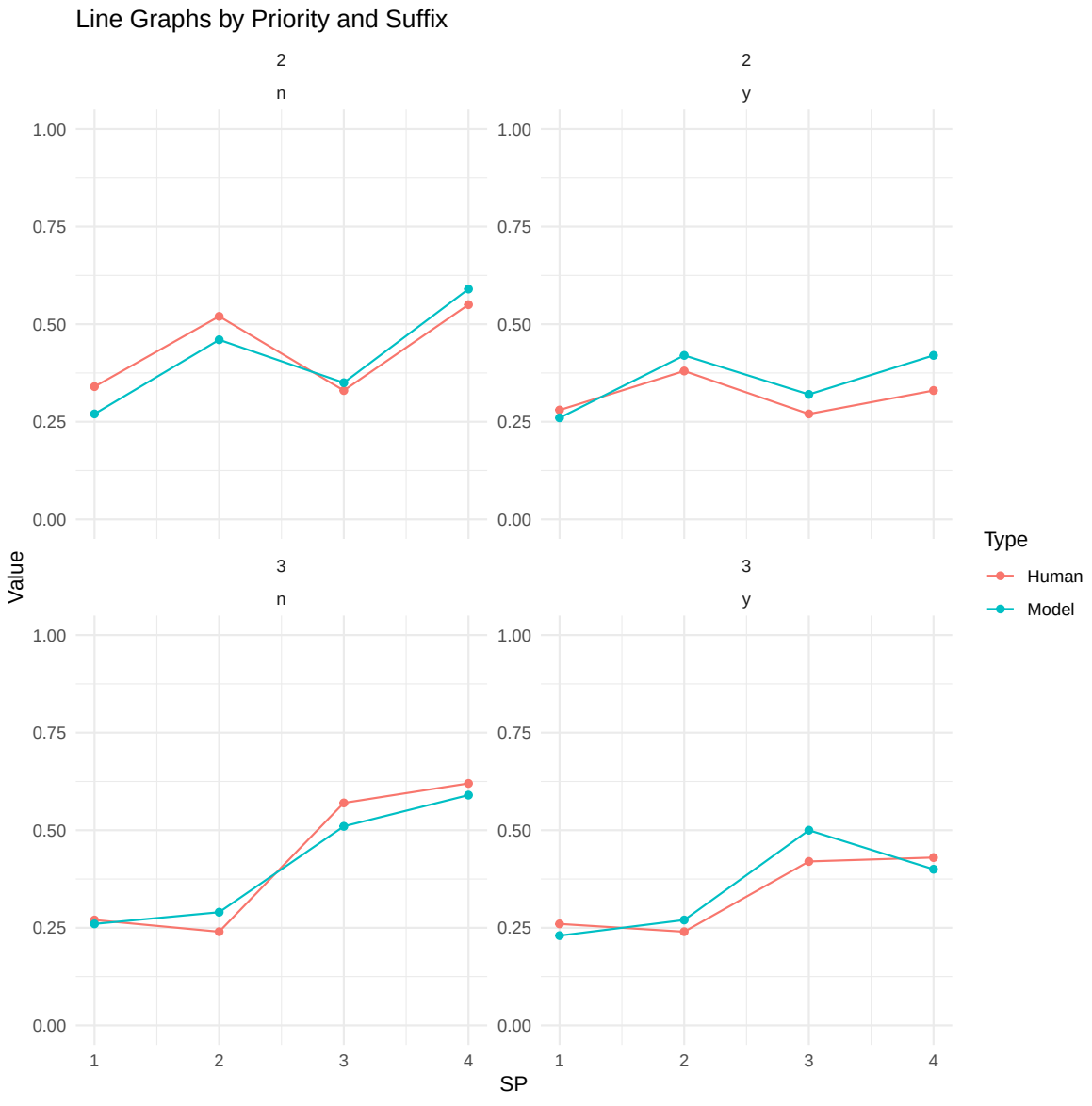
Chunk activations during a trial



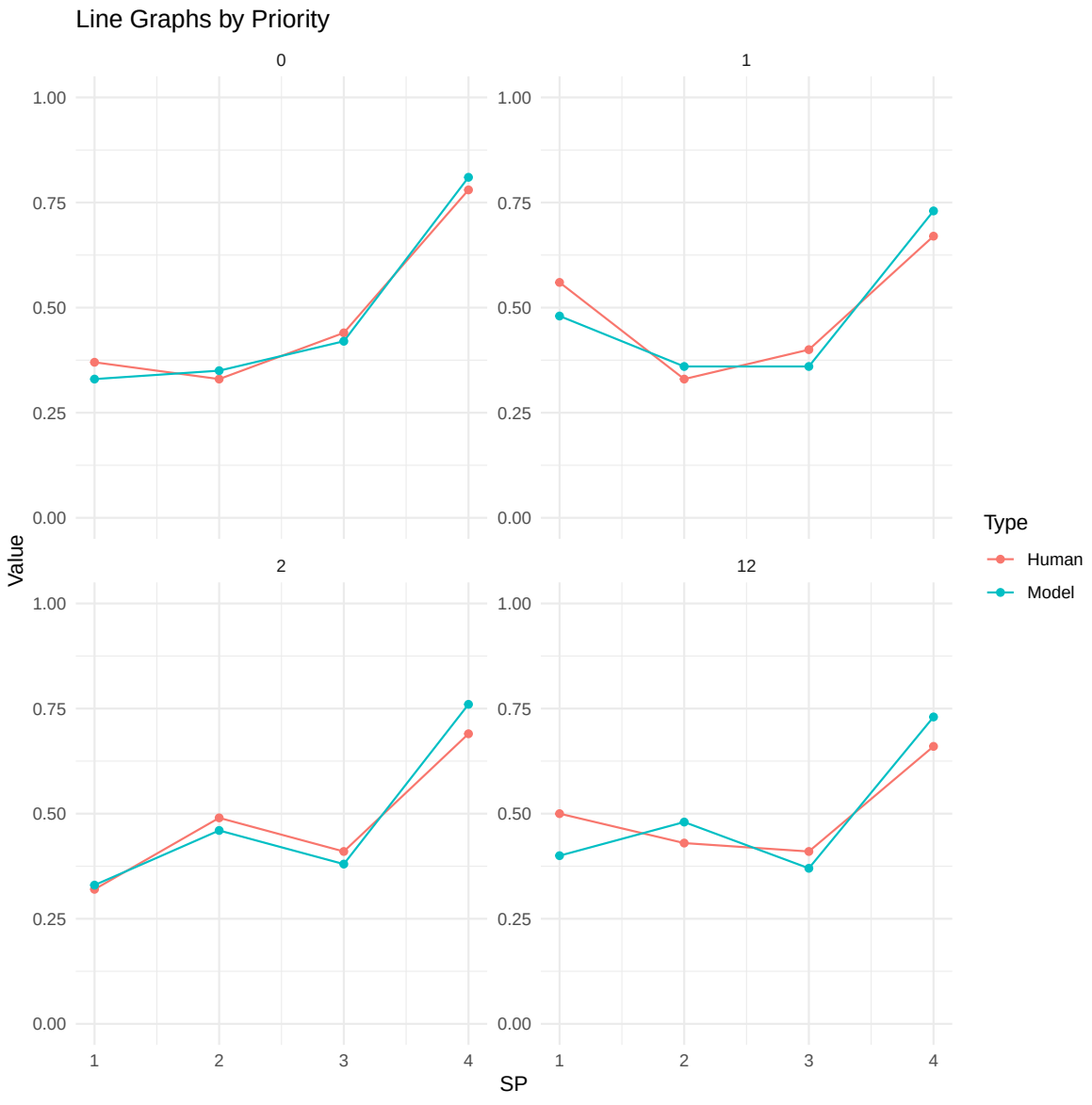
Chunk activations during a trial with noise



Experiment 1 model predictions



Experiment 2 model predictions



Conclusions

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  - How two items are prioritised
    - MCM Central executive alternates refreshing between prioritised items while processing new stimuli during trial
    - ACT-R Chunks activations refreshed once

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- ACT-R
  - Representations and mechanisms developed and tested over decades
  - Impose strong constraints on models

References i

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