Modelling the effect of prioritisation in visual working memory

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Overview

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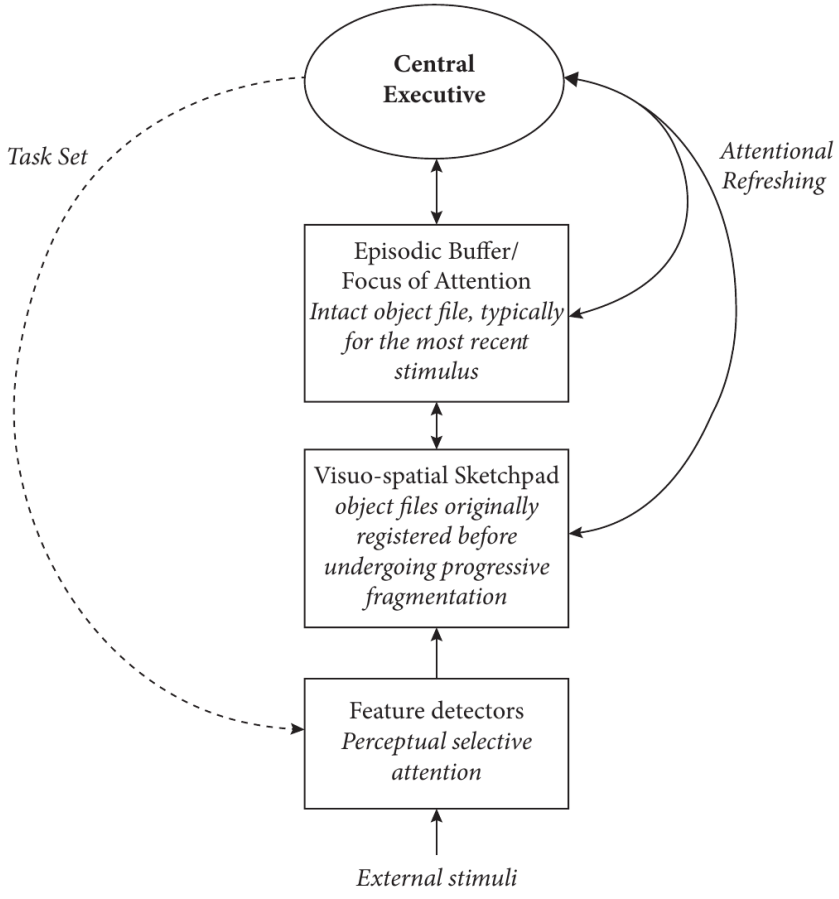
- ACT-R model of Hitch et al. (2018), experiments 1 and 2
  - Implements stimulus prioritisation
  - Provides an alternative account for improvement in recall

The focus of attention and visual working memory

- Episodic buffer limited capacity store in VSWM (Baddeley, 2000)
- Identified with focus of attention
- Contents determined by
  - Bottom-up perceptual processes
  - Top-down executive processes

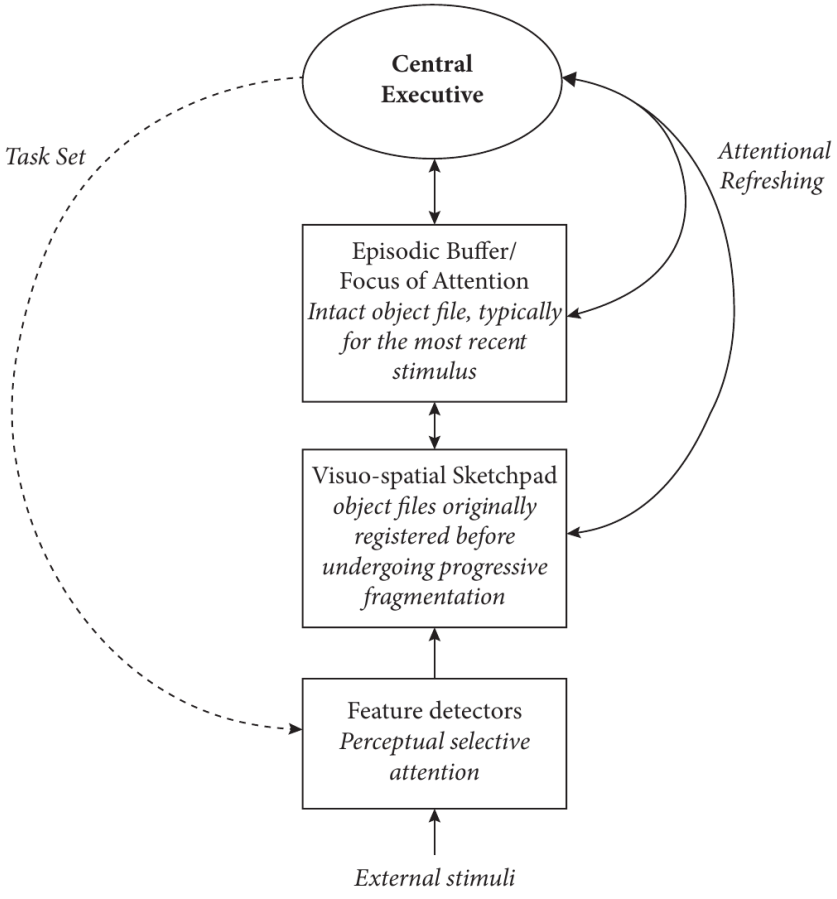


Visuo-spatial working memory (Baddeley et al., 2020)

The focus of attention and visual working memory

- Attentional refreshing
  - Maintains items in episodic buffer
  - Prevents items being overwritten by perceptual stimuli
- Prioritisation tasks

  Certain stimuli given higher value for recall (Hitch et al., 2018)



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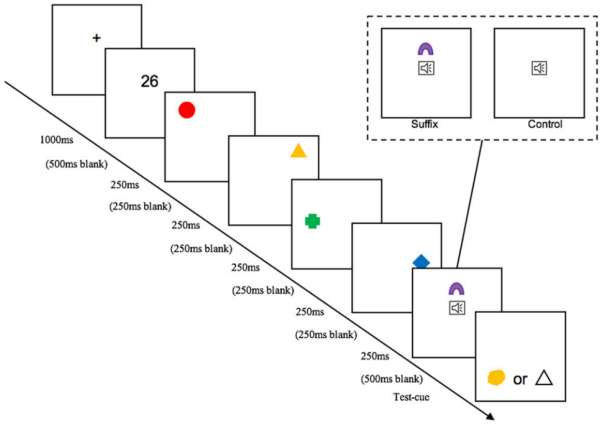
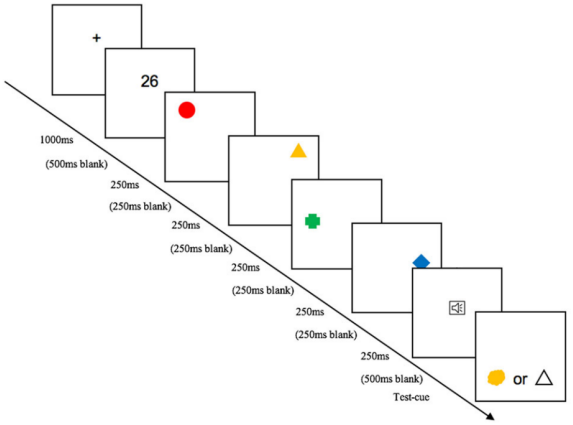
Experiment designs



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

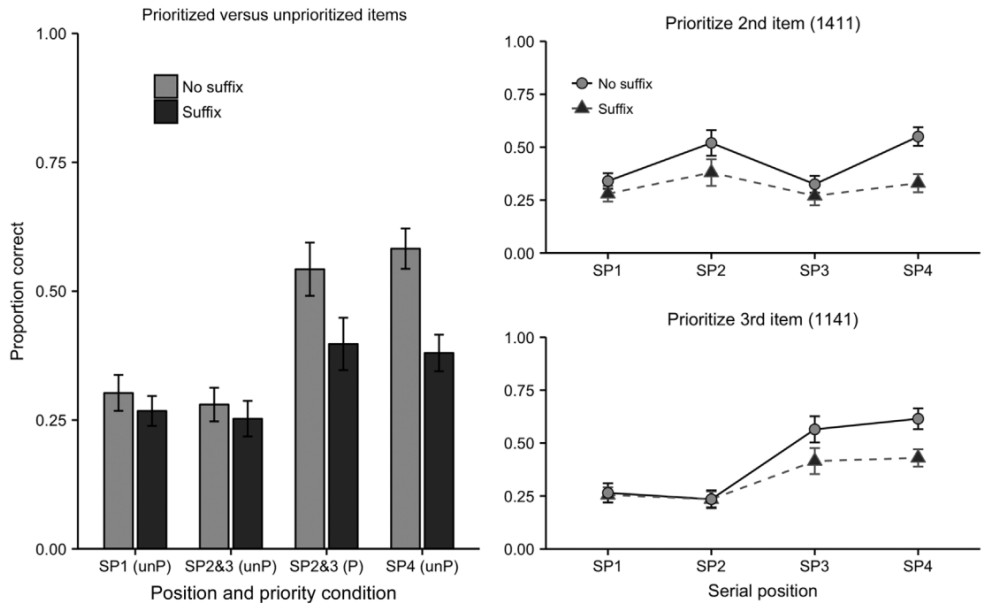


Exp 2 (4×4)

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

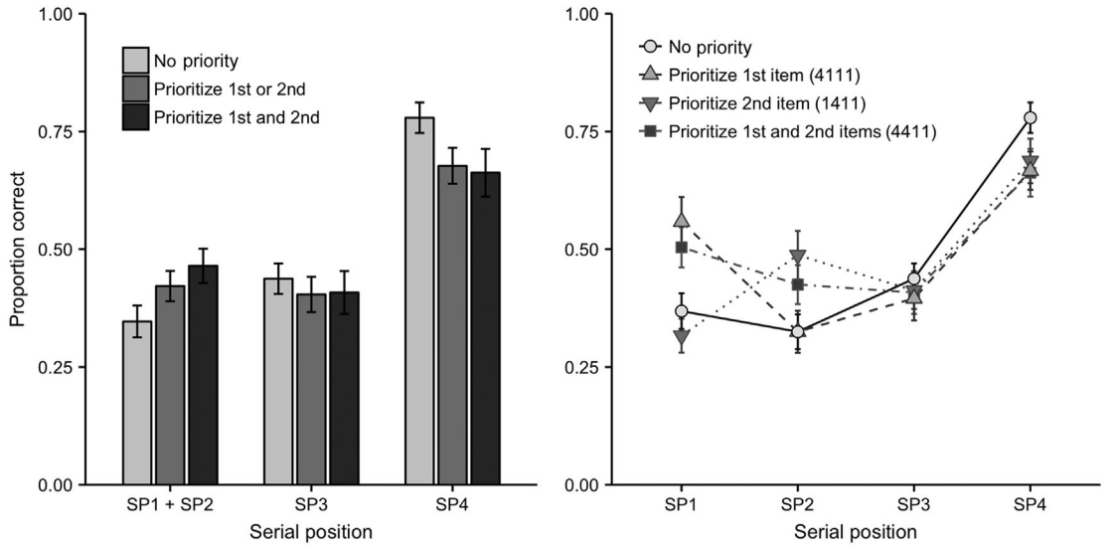
- Prioritisation on recency
- 1 Priority (0 | 1 | 2 | 1 & 2)
- 2 Cue SP (1 | 2 | 3 | 4)
- No suffix

Experiment 1 results



- SP2 and SP3
  - Prioritisation improved recall
  - Improvement reduced by suffix (sig for SP3)
- SP4
  - Recency effect found
  - Decreased by suffix and prioritisation (sig for SP2)

Experiment 2 results



- SP1 and SP2
  - Sig better when prioritised (either alone or together)
  - No sig diff between effects of prioritising one or two items
- SP3 No sig diff between the four conditions
- SP4 Sig better for baseline than priority conditions

Explanation of results

- Maintaining items in episodic buffer by attentional refreshing
  - Improves recall of prioritised items by inhibiting overwriting by novel stimuli (i.e., SP4 and suffix)
  - Reduces recency effect but also affected by the suffix

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  - Improves recall of prioritised items by inhibiting overwriting by novel stimuli (i.e., SP4 and suffix)
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- Exp2: No sig diff between effects of prioritising one and two items
  - Attentional refreshing alternates between SP1 and SP2, moving them in turn into the episodic buffer
  - Cost incurred – slight reduction in accuracy for both compared to individual prioritisation

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Explanation of results

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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"
- Effects interpreted in terms of the probability of items occupying the focus of attention at test

Modelling the task in ACT-R

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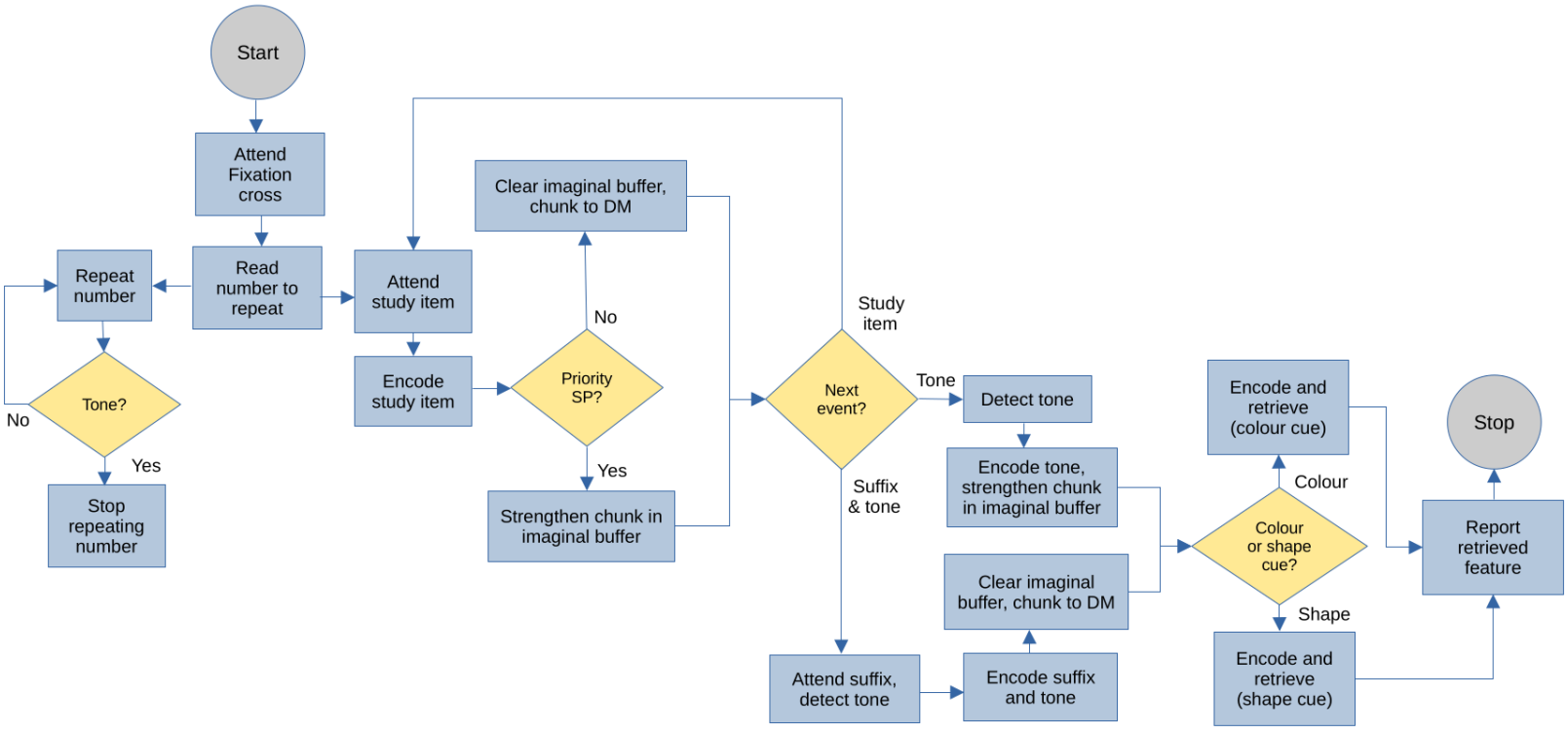
- Imaginal buffer is a one-chunk working memory, representing the focus of attention (Borst et al., 2010; Nijboer et al., 2016)
- ACT-R's WM functions are domain-general
  - Operate on the medium of knowledge chunks

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
  - The effect of the suffix on prioritisation and recency

Key features of the model



Study items

- Create chunk representing shape and colour in imaginal buffer
- Move chunk in DM when next item is processed

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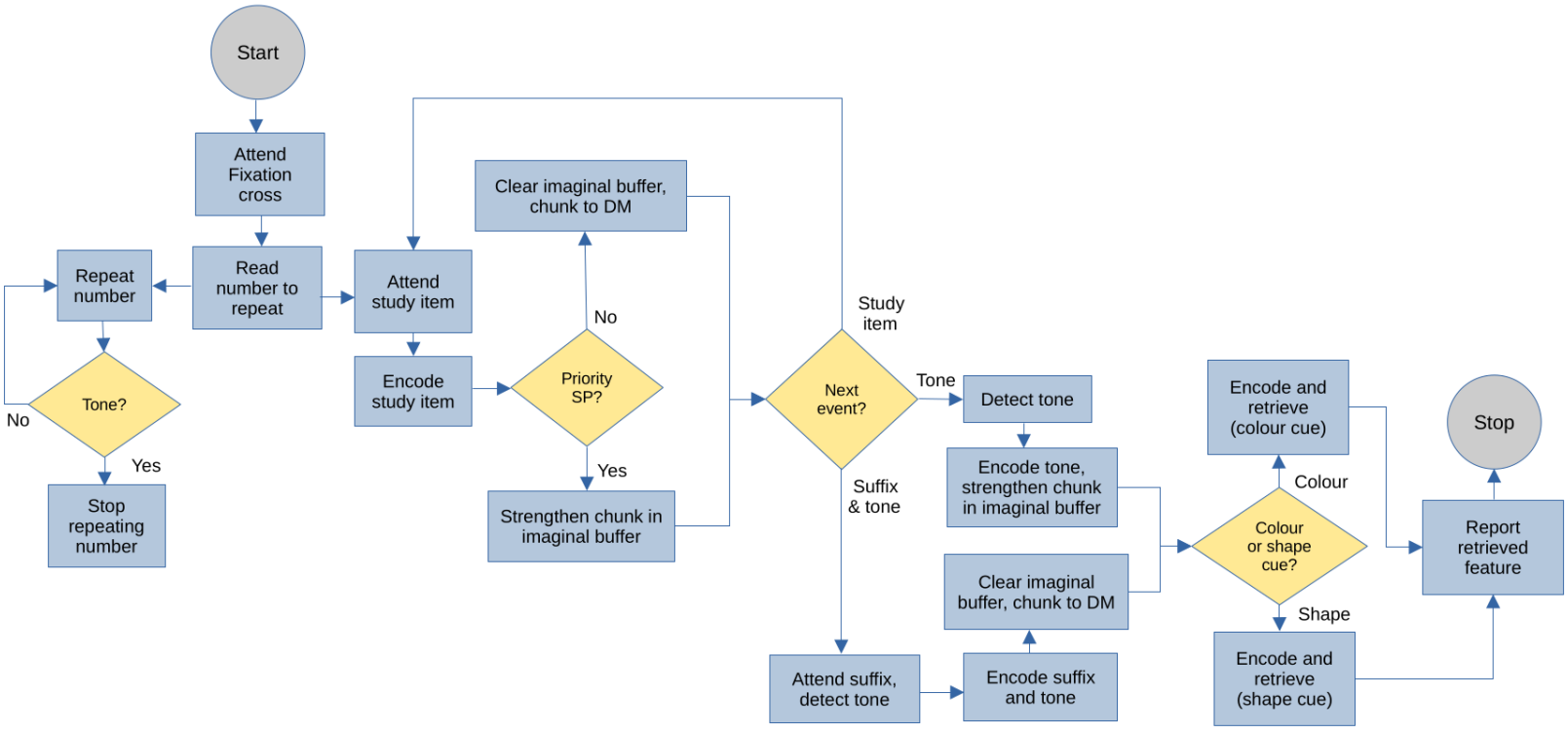

Prioritised items

- Before next item is processed, recreate existing chunk in imaginal buffer
- Results in merged chunk in DM with higher activation

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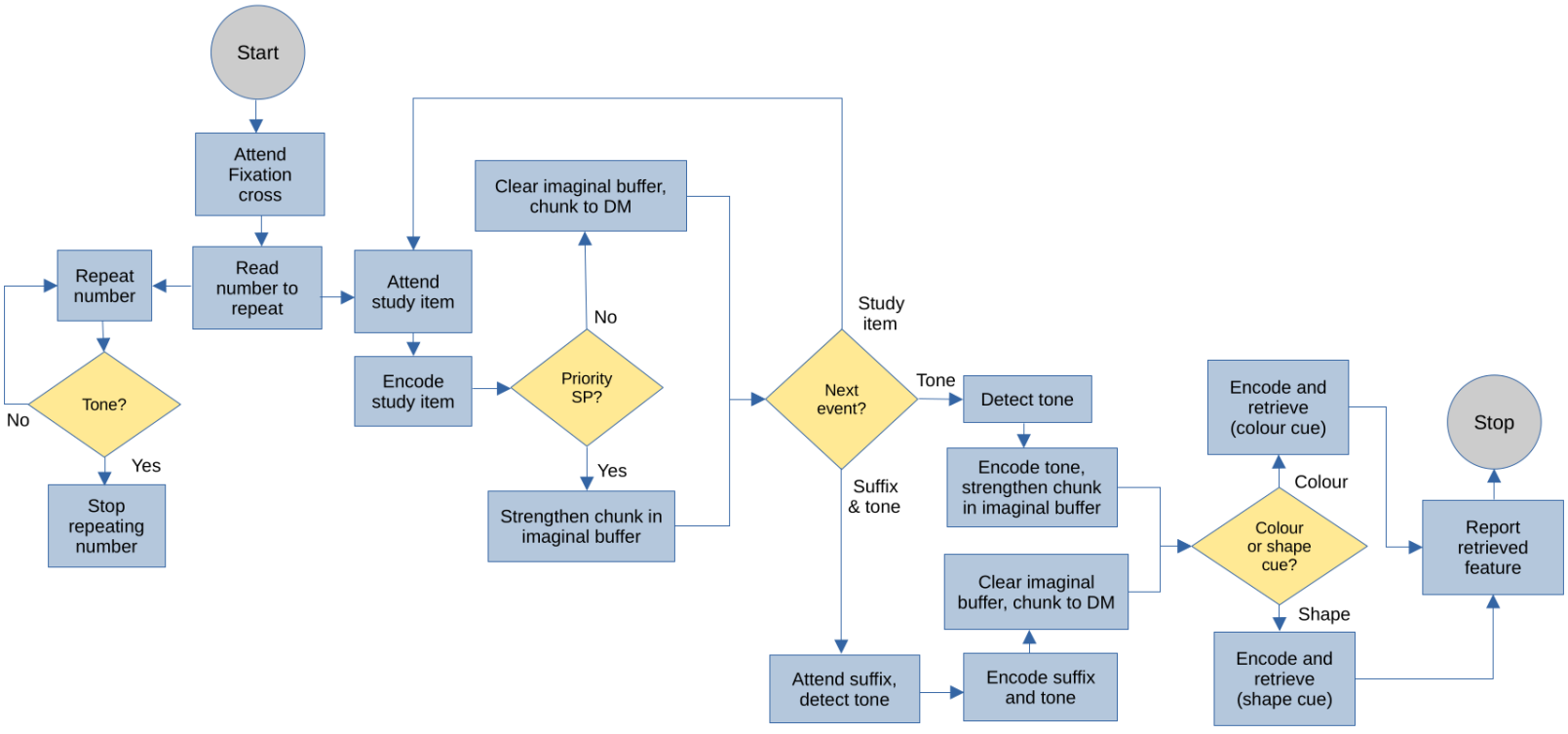

After the last study item

- Suffix Encode suffix as with study items
- No suffix Refresh item in imaginal buffer (SP4) as with prioritised items

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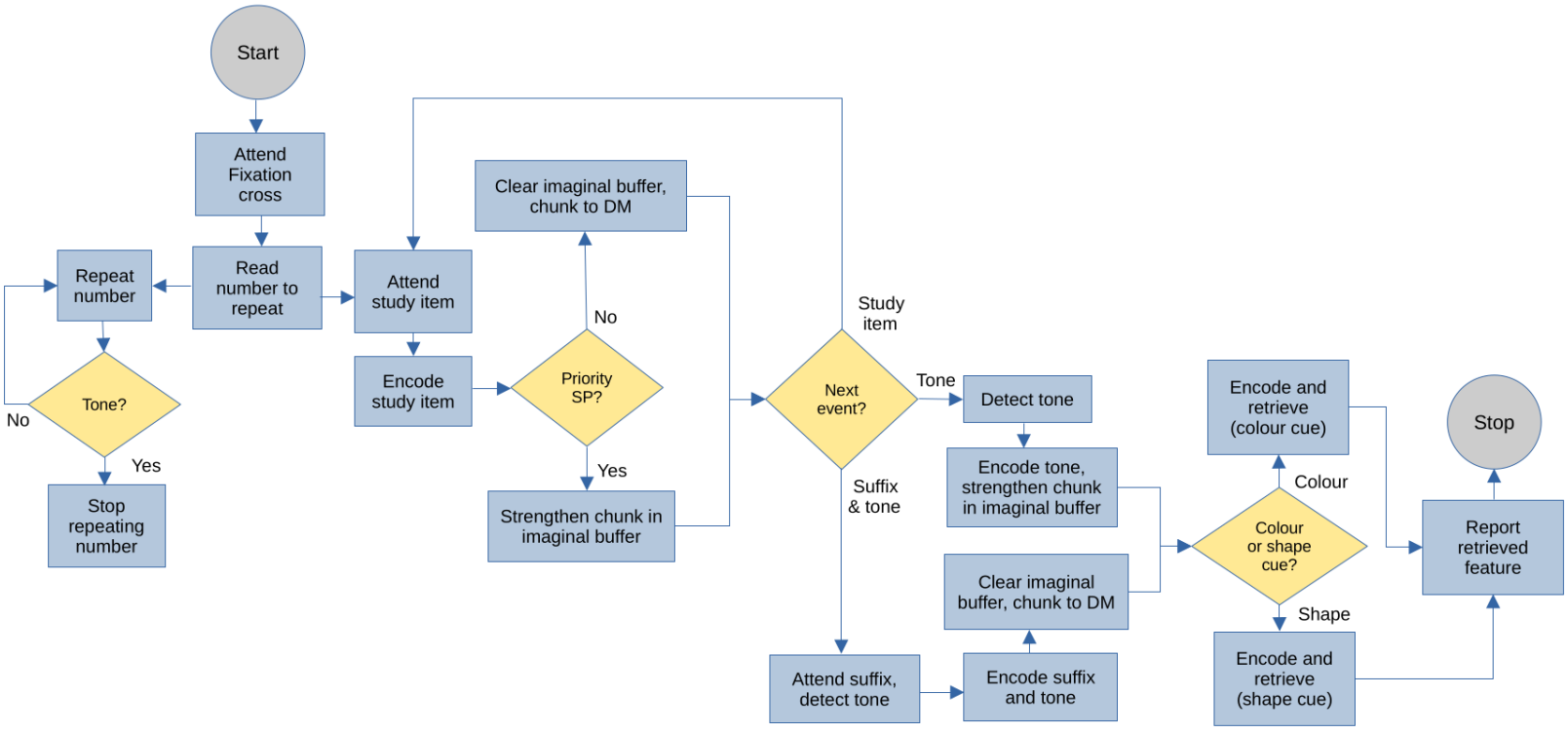
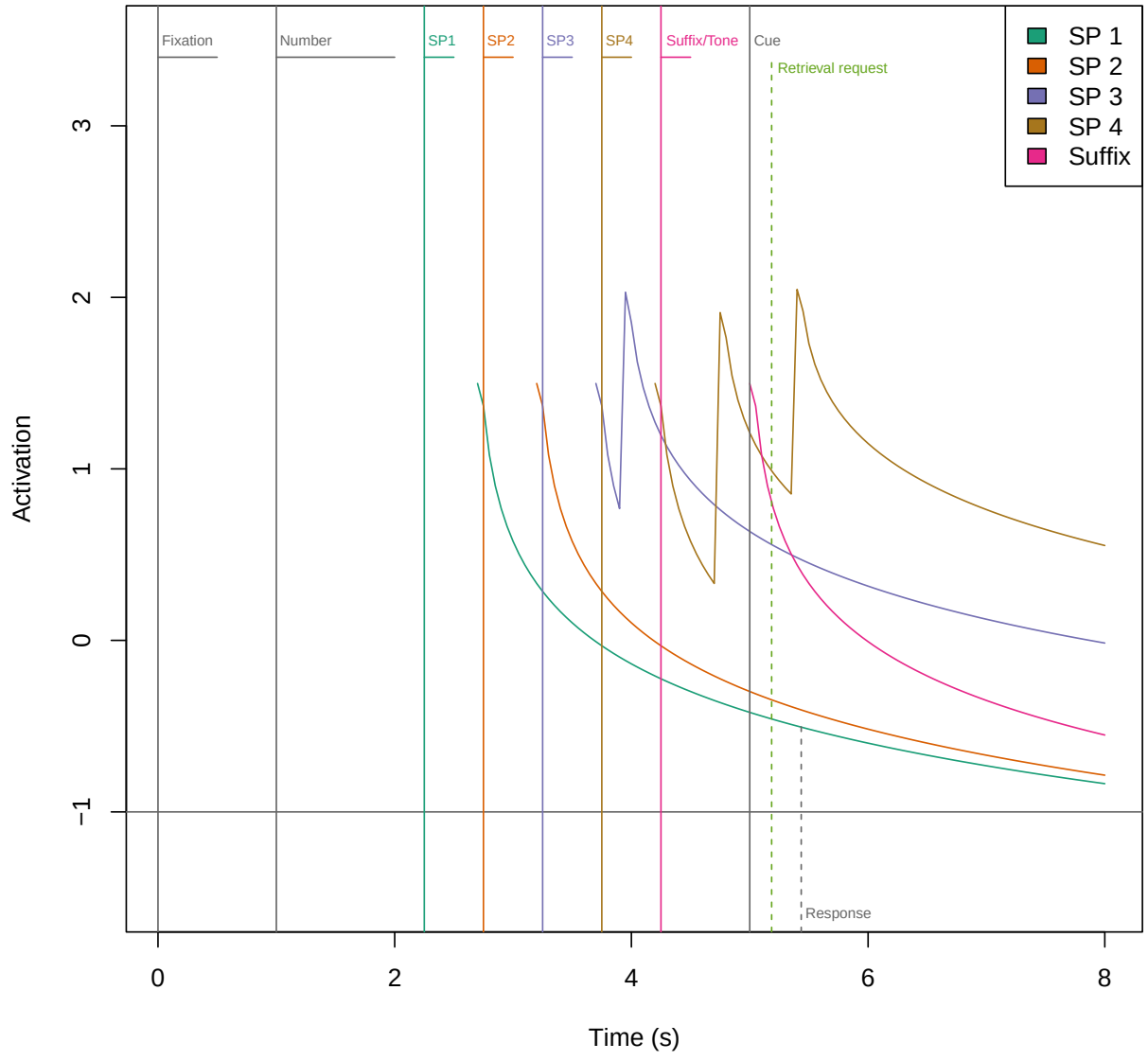


Crucial difference

- No competition for FoA during trial or at test
- Test performance determined by relative activations of chunks in DM

Chunk activations during a trial



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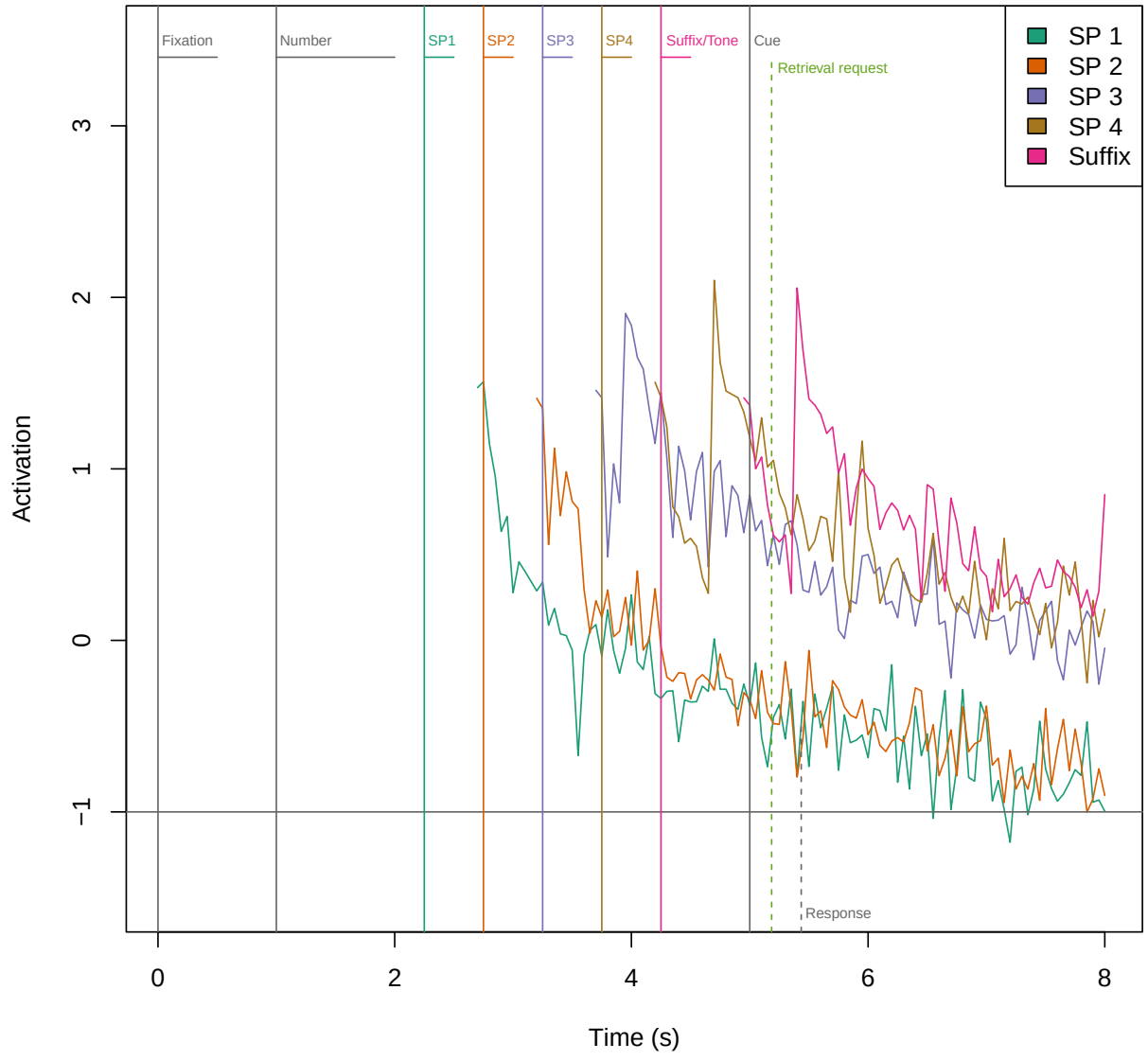
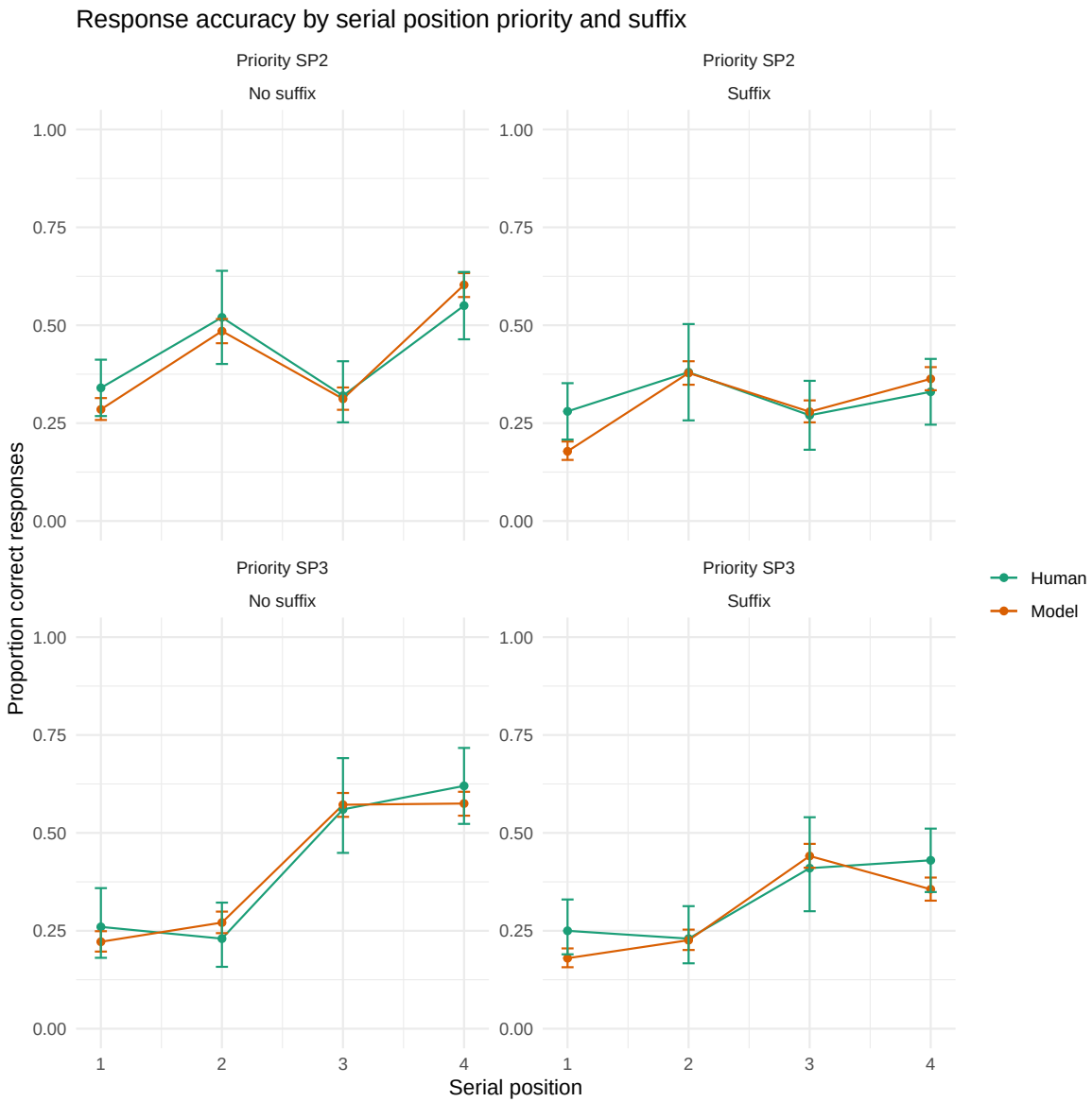


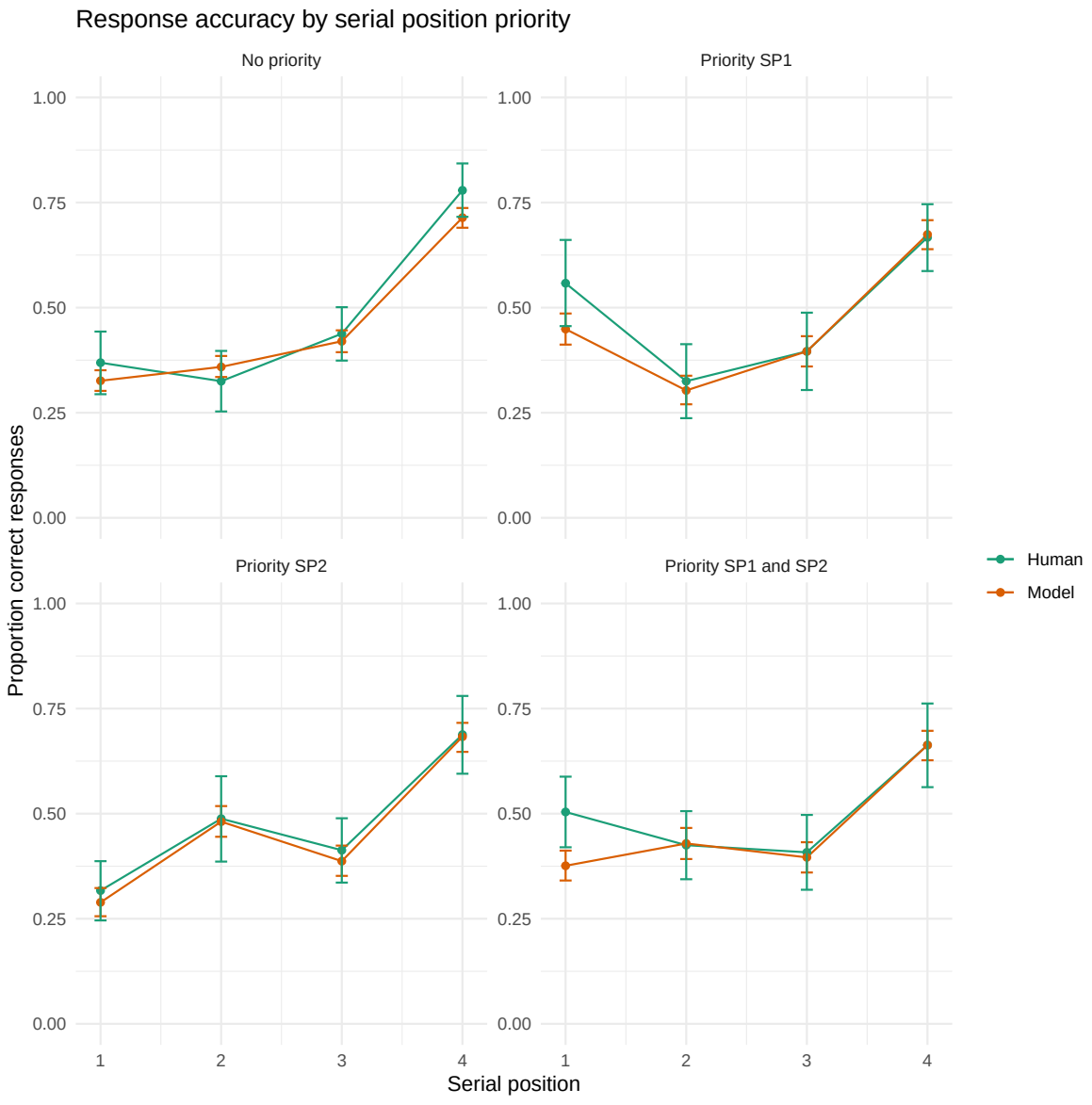
Parameters adjusted to fit the data

	Exp1	Exp2
Partial matching (:mp)	1.0	1.4
Activation noise (:ans)	0.45	0.4
:u encode tone and refresh SP4	0.0	0.55
:u encode tone	0.0	0.0
R^2	0.92	0.89
RMSD	0.05	0.07

Experiment 1 model predictions



Experiment 2 model predictions



Comparing the models

- Agreement
  - FoA a temporary store limited to one item/chunk
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- Disagreement
  - Effects of prioritisation and suffix at test due to:
    - MCM Current contents of FoA
    - ACT-R Chunk activations at retrieval
  - How multiple items are prioritised
    - MCM Central executive alternates refreshing between prioritised items while also processing new stimuli during trial
    - ACT-R Single boost of chunk activations

Future work

- Complete model of third experiment
  - Prioritise SP1 and SP2 with suffix condition
- Experiment (with Allen and Hitch) to differentiate accounts
  - Increasing cognitive load during trial (Fitamen et al., 2024)
  - Challenging as MCM doesn't make quantitative predictions

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References i

Allen, R. J., Atkinson, A., & Hitch, G. J. (2024). *Getting value out of working memory through strategic prioritisation; implications for storage and control.* *Quarterly Journal of Experimental Psychology*, *0*(0), 0. doi: 10.1177/17470218241258102.

Baddeley, A., & Hitch, G. L. (1974). *Working memory.* In G. A. Bower (Ed.), *Recent advances in learning and motivation* (pp. 47–89, Vol. 8). Academic Press.

Baddeley, A. (2000). *The episodic buffer: A new component of working memory?* *Trends in Cognitive Sciences*, *4*(11), 417–423. doi: 10.1016/s1364-6613(00)01538-2.

Baddeley, A., Hitch, G., & Allen, R. (2020). *A multicomponent model of working memory.* In *Working memory* (pp. 10–43). Oxford University Press. doi: 10.1093/oso/9780198842286.003.0002.

Borst, J. P., Taatgen, N. A., & van Rijn, H. (2010). *The problem state: A cognitive bottleneck in multitasking.* *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(2), 363–382. doi: 10.1037/a0018106.

Fitamen, C., Martin-Soelch, C., & Camos, V. (2024). *The role of attention on the impact of reward value on working memory prioritisation.* *International Workshop on Working Memory*. doi: 10.13140/RG.2.2.14044.81284.

Hitch, G. J., Hu, Y., Allen, R. J., & Baddeley, A. D. (2018). *Competition for the focus of attention in visual working memory: Perceptual recency versus executive control.* *Annals of the New York Academy of Sciences*, *1424*(1), 64–75. doi: 10.1111/nyas.13631.

References iii

Hu, Y., Hitch, G. J., Baddeley, A. D., Zhang, M., & Allen, R. J. (2014). *Executive and perceptual attention play different roles in visual working memory: Evidence from suffix and strategy effects.* *Journal of Experimental Psychology: Human Perception and Performance*, *40*(4), 1665–1678. doi: 10.1037/a0037163.

Nijboer, M., Borst, J., van Rijn, H., & Taatgen, N. (2016). *Contrasting single and multi-component working-memory systems in dual tasking.* *Cognitive Psychology*, *86*, 1–26. doi: 10.1016/j.cogpsych.2016.01.003.