A Theory of Memory for Items and Associations

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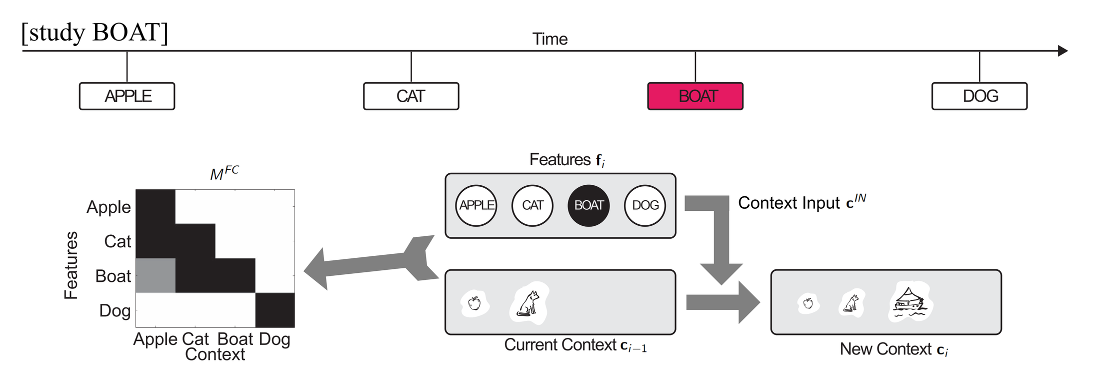
INTRODUCTION

- In episodic memory, **item-specific information** represents the encoding of an item occurring in a particular context, while **associative information** represents the encoding of the relation between two co-occurring items.
- **Context Maintenance and Retrieval (CMR)** models conceive of episodic memory as the interaction between content and context. Recalling a memory reinstates its earlier context, which in turn updates the present state of context and associates with subsequent experiences. CMR Models have offered an elegant account for a wide range of phenomena observed in studies of free recall (Lohnas, Polyn, & Kahana, 2015; Pazdera & Kahana, 2022).
- We aim to provide a unified theoretical account of memory for items and associations within the framework of CMR models.

MODEL

ITEM

Encoding



Update memory matrix:

$$M_t^{FC} = M_{t-1}^{FC} + \gamma_{FC} \mathbf{c}_{i-1} \mathbf{f}_i^\top$$

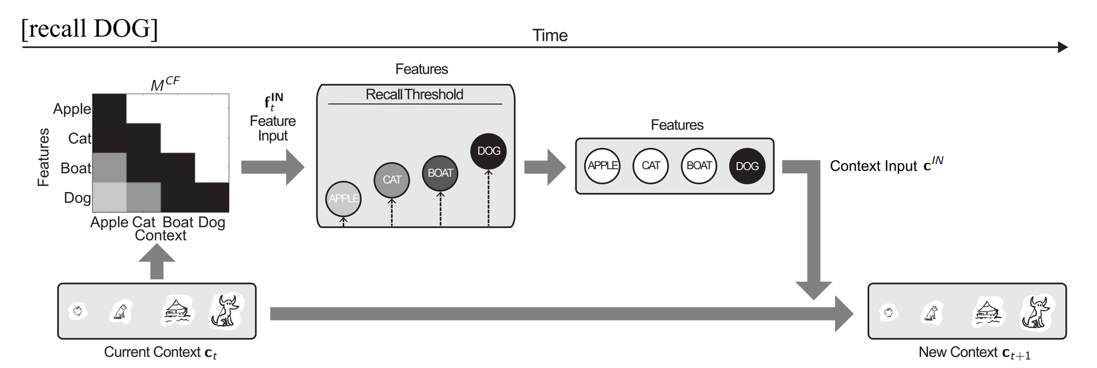
$$M_t^{CF} = M_{t-1}^{CF} + \phi_i \gamma_{CF} \mathbf{f}_i \mathbf{c}_{i-1}^\top$$

Update context:

$$\mathbf{c}^{IN} = M^{FC} \mathbf{f}_i$$

$$\mathbf{c}_i = \rho_i \mathbf{c}_{i-1} + \beta \frac{\mathbf{c}^{IN}}{||\mathbf{c}^{IN}||}$$

Recall
(free recall)

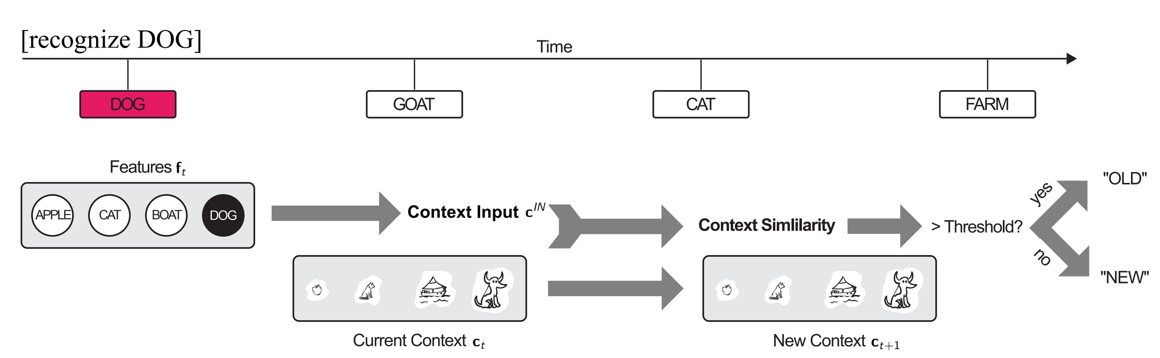


Retrieve with context:

$$\mathbf{f}_t^{\mathbf{IN}} = M^{CF} \mathbf{c}_t$$

Retrieved Item = Leaky Accumulator($\mathbf{f}_t^{\mathbf{IN}}$)

Recognition



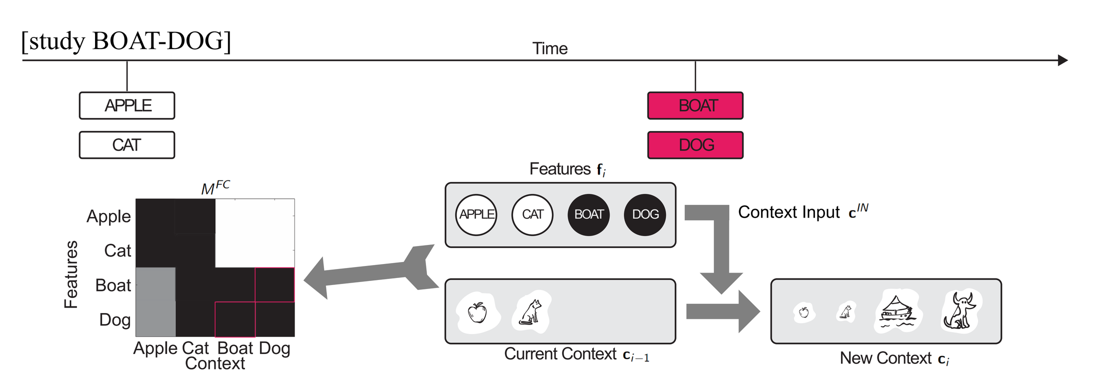
Compare context with item:

$$\mathbf{c}^{IN} = M^{FC} \mathbf{f}_t$$

Context Similarity $= \mathbf{c}^{IN} \cdot \mathbf{c}_t$

ASSOCIATION

Encoding



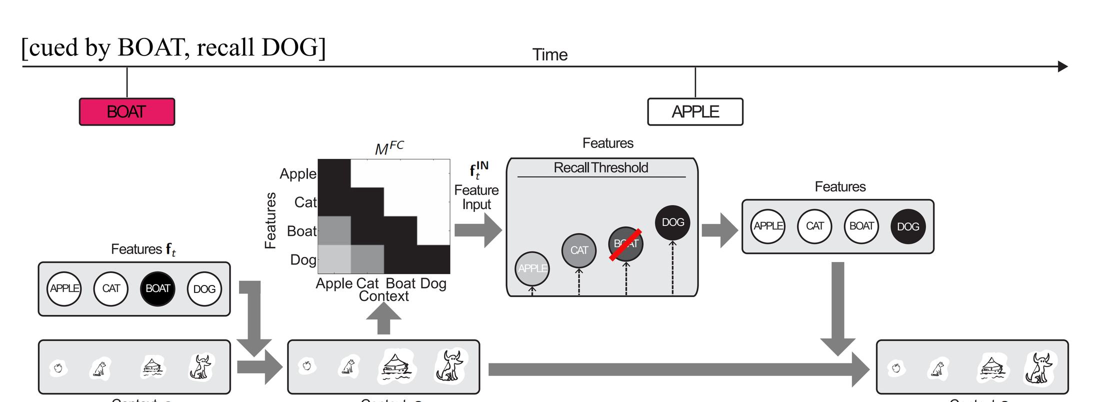
Update memory matrix:

$$\mathbf{f}_i = \mathbf{f}_{i_1} + \mathbf{f}_{i_2}$$

$$M_t^{FC} = M_{t-1}^{FC} + \gamma_{FC} \mathbf{c}_{i-1} \mathbf{f}_i^\top + d_{assoc}(\mathbf{f}_{i_1} \mathbf{f}_{i_2}^\top + \mathbf{f}_{i_2} \mathbf{f}_{i_1}^\top)$$

$$M_t^{CF} = M_{t-1}^{CF} + \gamma_{CF} \mathbf{f}_i \mathbf{c}_{i-1}^\top + d_{assoc}(\mathbf{f}_{i_1} \mathbf{f}_{i_2}^\top + \mathbf{f}_{i_2} \mathbf{f}_{i_1}^\top)$$

Recall
(cued recall)



First, update context:

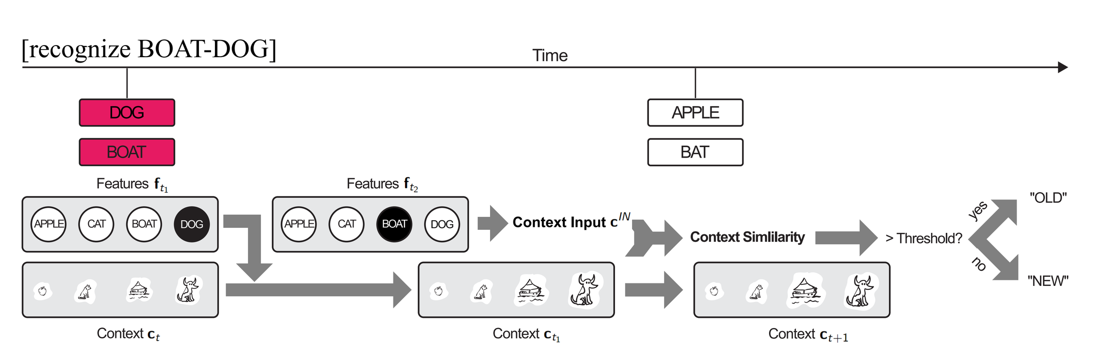
$$\mathbf{c}_{t_1} = \rho_t \mathbf{c}_t + \beta \frac{M^{FC} \mathbf{f}_t}{||M^{FC} \mathbf{f}_t||}$$

Then, retrieve with context:

$$\mathbf{f}_t^{\mathbf{IN}} = M^{CF} \mathbf{c}_{t_1}$$

Retrieved Item = Leaky Accumulator($\mathbf{f}_t^{\mathbf{IN}}$)

Recognition



First, Update context with the first item:

$$\mathbf{c}_{t_1} = \rho_t \mathbf{c}_t + \beta \frac{M^{FC} \mathbf{f}_{t_1}}{||M^{FC} \mathbf{f}_{t_1}||}$$

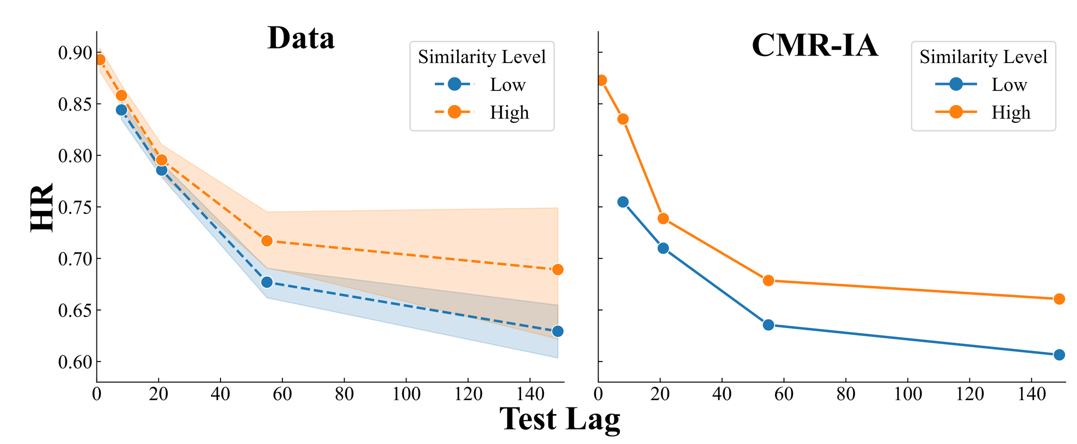
Then, compare context with the second item:

$$\mathbf{c}^{IN} = M^{FC} \mathbf{f}_{t_2}$$

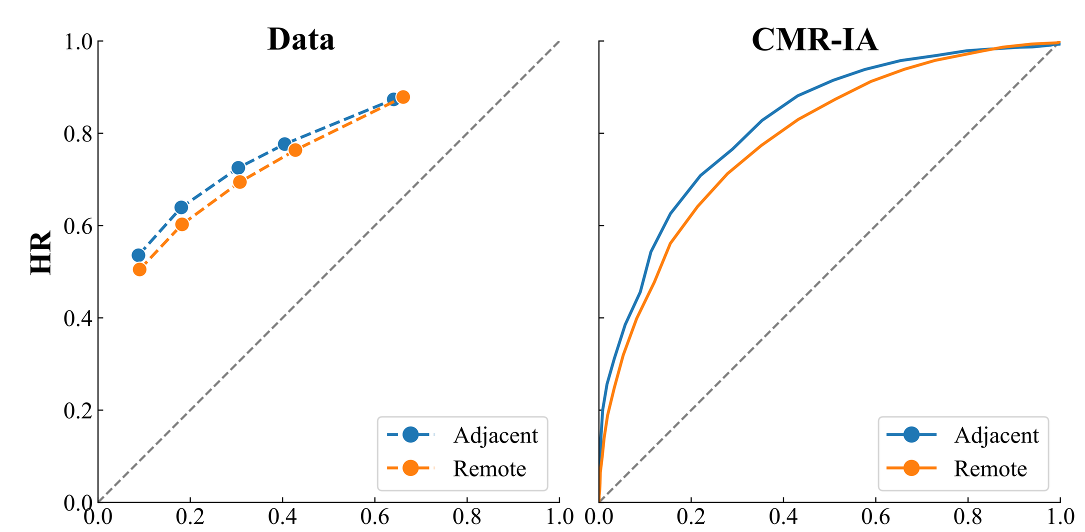
Context Similarity $= \mathbf{c}^{IN} \cdot \mathbf{c}_{t_1}$

SIMULATION RESULTS

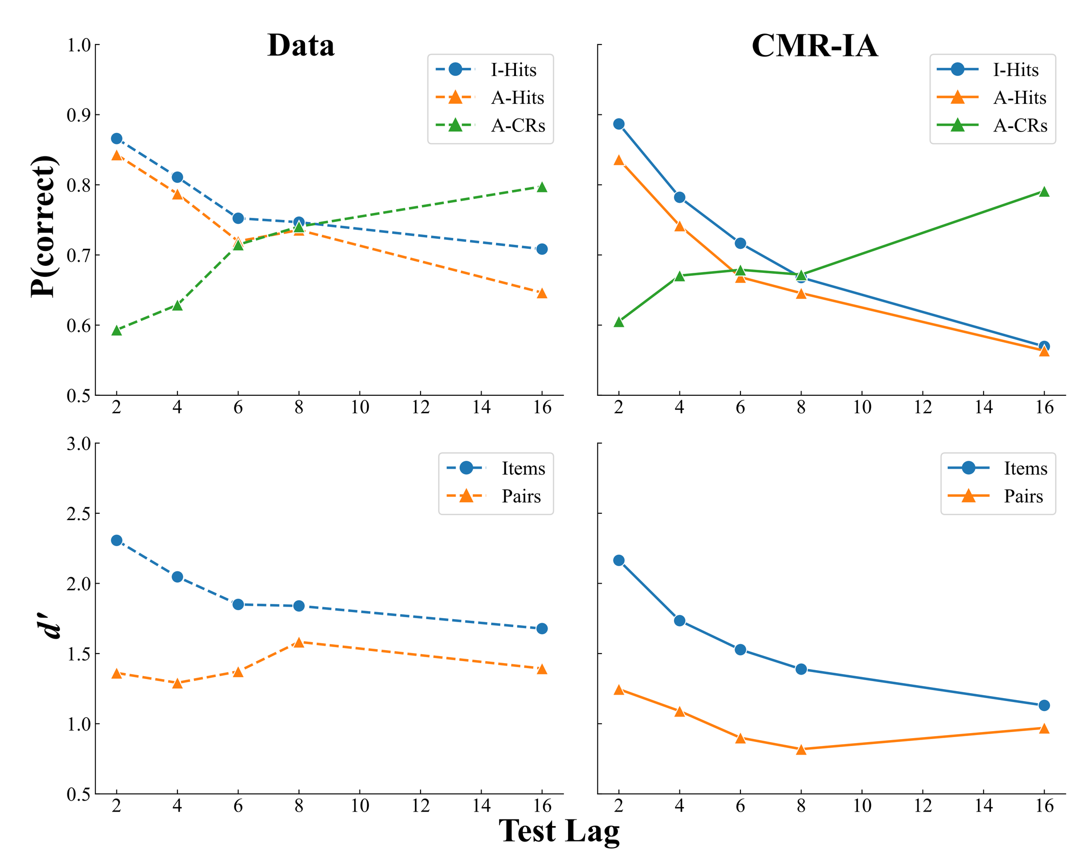
1. Recency and Similarity Effects in Item Recognition



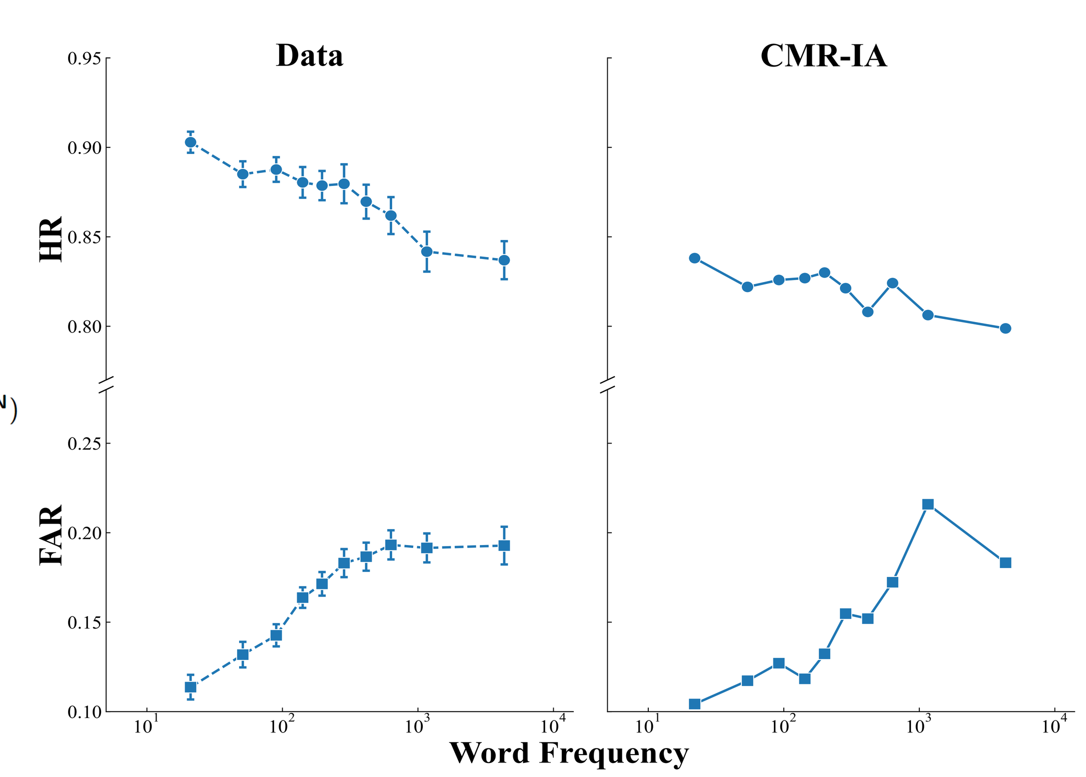
2. Successive-probe Contiguity Effects in Item Recognition



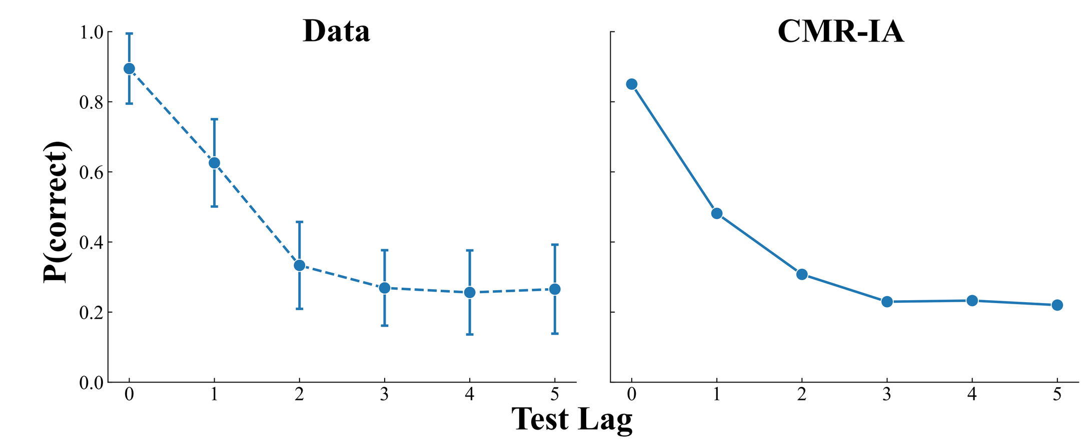
3. Differential Forgetting of Items and Associations



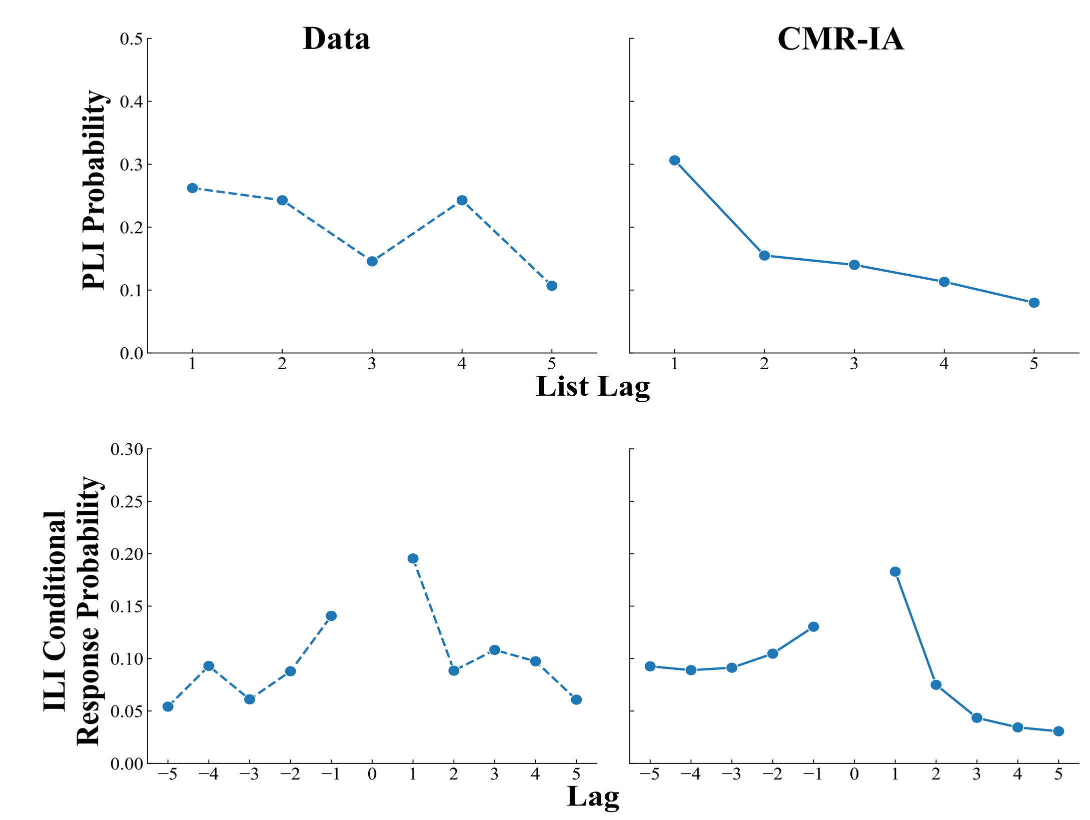
4. Word Frequency Effects



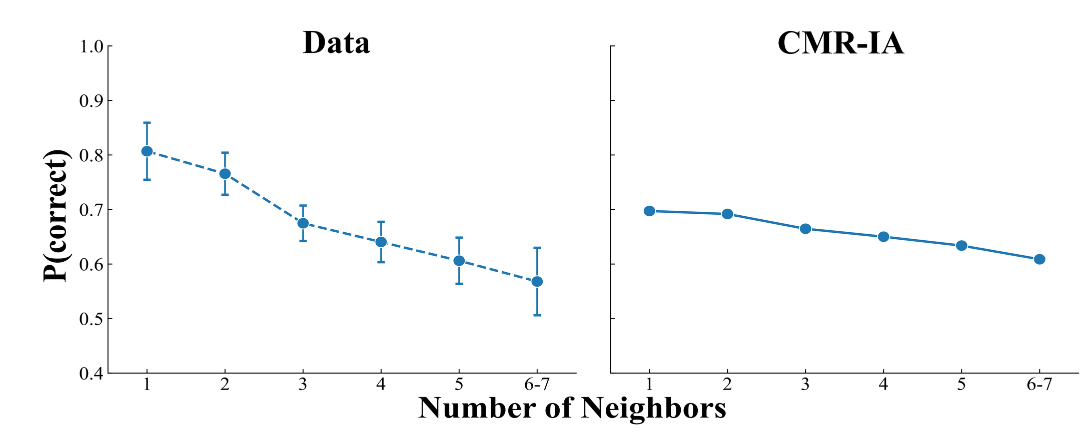
5. Serial Position Effects in Cued Recall



6. PLIs and ILIs in Cued Recall



7. Similarity Effects in Cued Recall



8. Associative Symmetry

		Congruent				Incongruent		
			Test 1				Test 1	
			+	-			+	-
Data	Test 2	+	0.319	0.012	Test 2	+	0.293	0.122
		-	0.006	0.663		-	0.049	0.537
			Yule's $\mathcal{Q} = 0.94$				Yule's $\mathcal{Q} = 0.96$	
			Test 1				Test 1	
			+	-			+	-
CMR-IA	Test 2	+	0.299	0.049	Test 2	+	0.297	0.097
		-	0.030	0.623		-	0.033	0.574
			Yule's $\mathcal{Q} = 0.97$				Yule's $\mathcal{Q} = 0.94$	

9. Successive Tests of Recognition and Cued Recall

Data / CMR-IA

Condition	P(Rc)	HR	FAR	d'	$\mathcal{Q}$
Item	0.19 (0.01)	0.67 (0.02)	0.15 (0.02)	1.56 (0.07)	0.57 (0.05)
	0.090 (.001)	0.611 (.004)	0.249 (.005)	0.971 (.015)	0.573 (.016)
Pair	0.30 (0.03)	0.80 (0.02)	0.12 (0.01)	2.20 (0.11)	0.71 (0.04)
	0.307 (.006)	0.807 (.004)	0.010 (.001)	3.083 (.028)	0.730 (.015)
Associative	0.42 (0.04)	0.72 (0.03)	0.22 (0.02)	1.46 (0.13)	0.81 (0.02)
	0.404 (.010)	0.808 (.004)	0.155 (.004)	1.917 (.022)	0.791 (.013)

10. Successive Tests of Item and Assoc Recognition

Data / CMR-IA

Condition	**Test 1 Cue**	P("Yes")	**Test 2 Cue**	P("Yes")	Yule's $\mathcal{Q}$
Different Item	A	0.82 (.020)	B	0.68 (.030)	0.26 (0.10)
	B	0.747(.014)	A	0.749(.014)	0.296(.044)
Item/Pair	A	0.82 (.016)	A-B	0.85 (.020)	0.64 (0.12)
	B	0.766(.011)	A-B	0.910(.007)	0.684(.029)
Pair/Item	A-B	0.91 (.018)	A	0.85 (.021)	0.59 (0.10)
		0.885(.010)	B	0.759(.014)	0.606(.032)
Same Item	A	0.81 (.017)	A	0.82 (.017)	0.86 (0.03)
	B	0.789(.013)	B	0.805(.012)	0.861(.018)
Intact Pair	A-B	0.90 (.022)	A-B	0.92 (.019)	0.94 (0.02)
		0.889(.017)		0.895(.014)	0.843(.012)
Repeated Lure	X	0.070 (.014)	X	0.15 (.018)	0.54 (0.12)
	X-Y	0.012(.022)	X-Y	0.016(.024)	0.598(.035)
Non-repeated Lure	C	0.070 (.009)	D	0.06 (.009)	—
	E-F	0.113(.005)	G-H	0.109(.004)	

CONCLUSIONS

- We refer to our models as Context Maintenance and Retrieval Model for Items and Associations (CMR-IA).
- CMR-IA provides a unified account for a wide range of phenomena in recognition and cued recall as well as their interactions. It emphasizes the importance of retrieved context in episodic memory.
- Next steps: develop a mechanism for reaction time; add source features of study items.

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