Assessing neural computations supporting memory in 4-year-olds using a latent variable approach

Work in progress

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HCCCL
Hippocampal Circuit and Code for Cognition

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1. INTRODUCTION

Two distinct neural computations performed by the hippocampus contribute differentially to behavioral memory outcomes[1].

Pattern separation (PS)—supported by the dentate gyrus (DG) of the hippocampus—is a computation that transforms highly similar representations into non-overlapping representations, supporting specificity of memories [2].

Pattern completion (PC)—supported by the cornu ammonis 3(CA3) of the hippocampus—is a computation that restores degraded or incomplete representations based on previously stored information, supporting generalization [3].
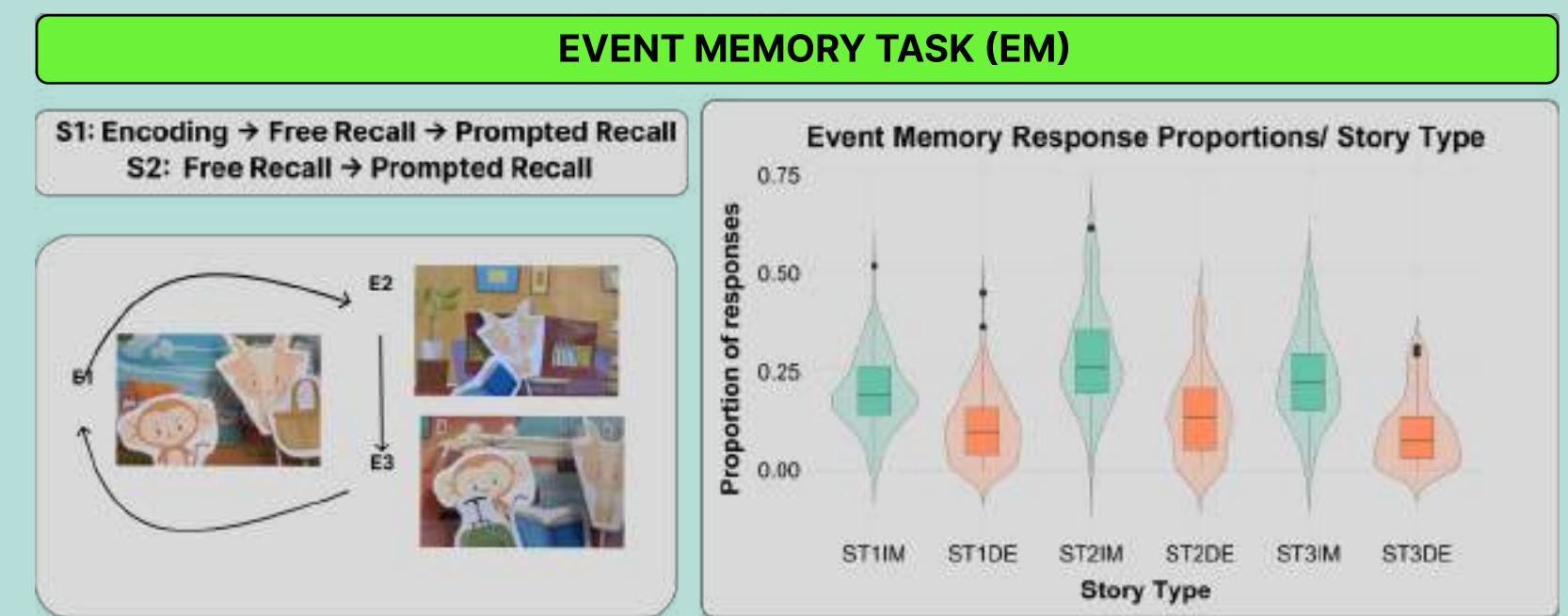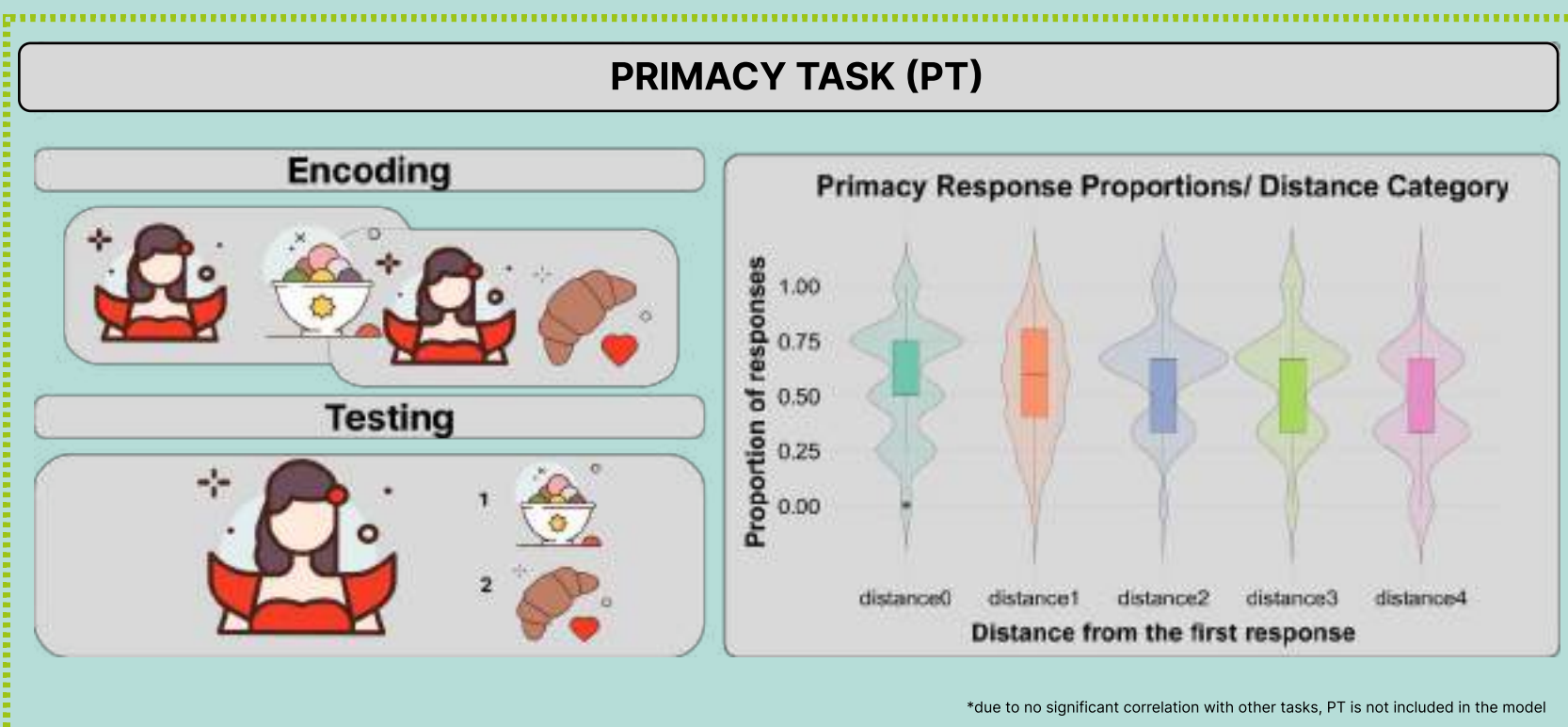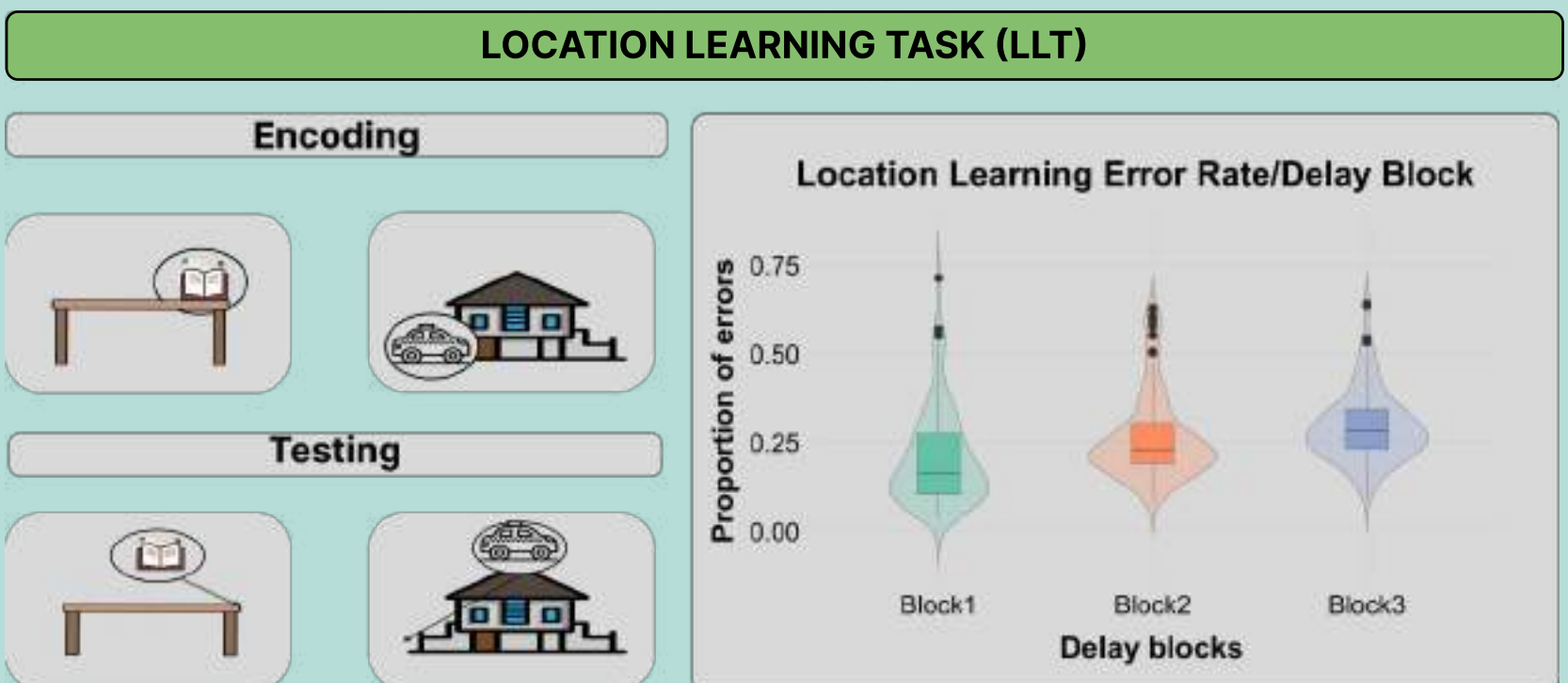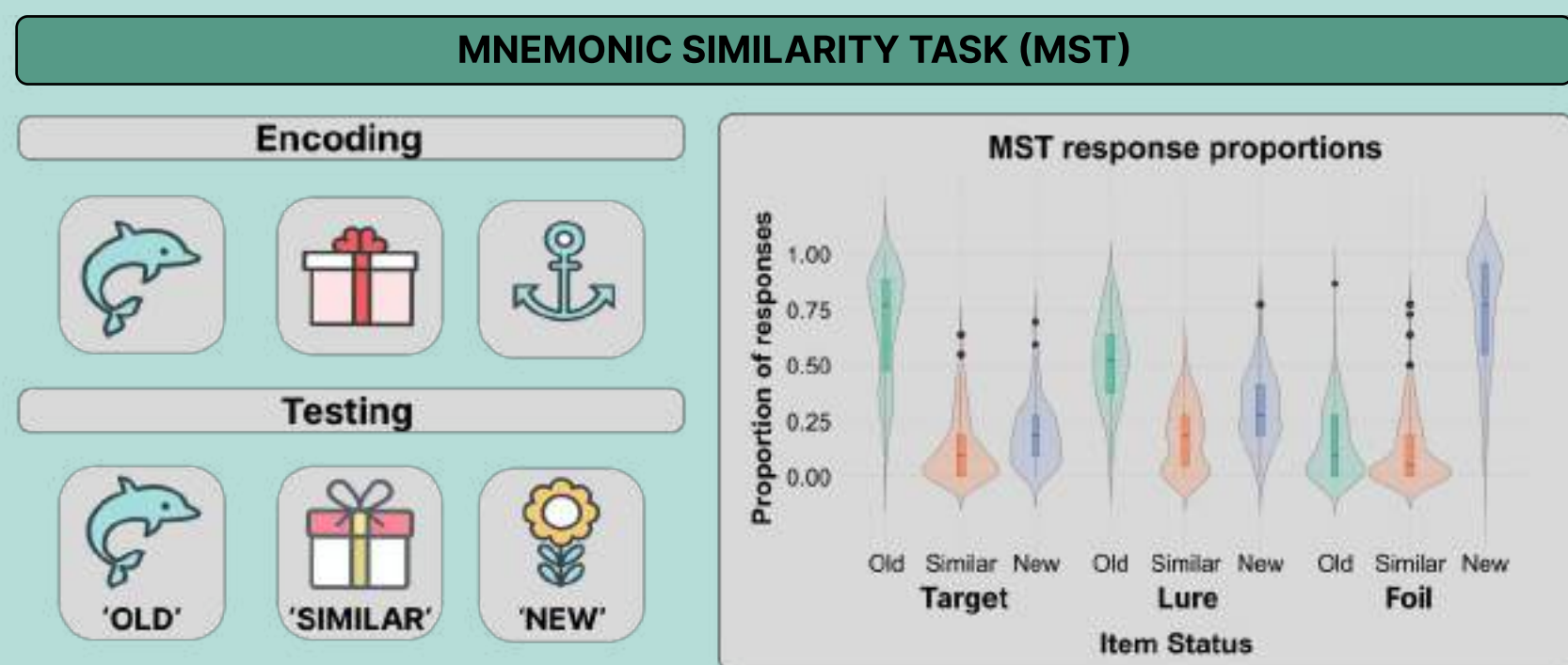
Differential development of PS and PC drives the shift from a focus on abstracting regularities through experience to remembering unique events in early ontogeny [4].
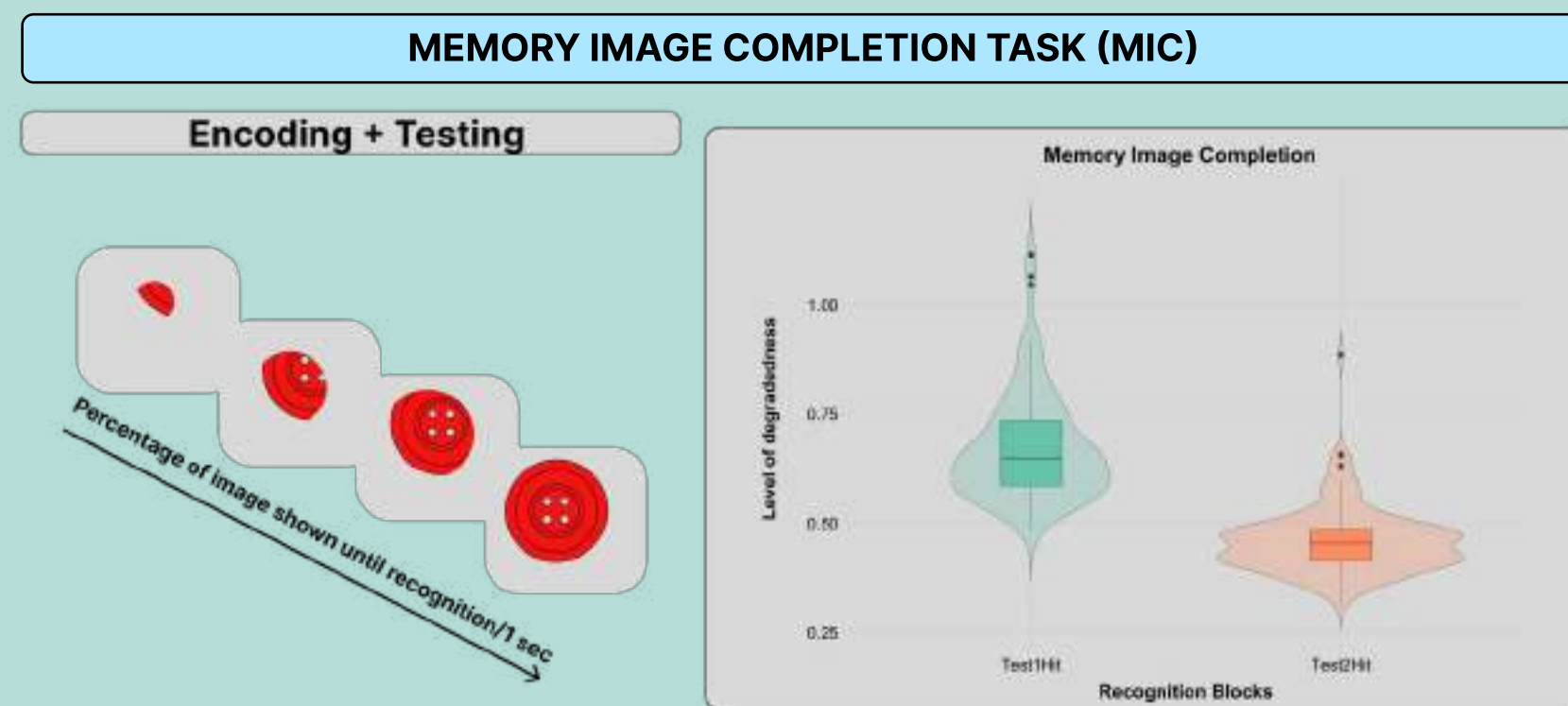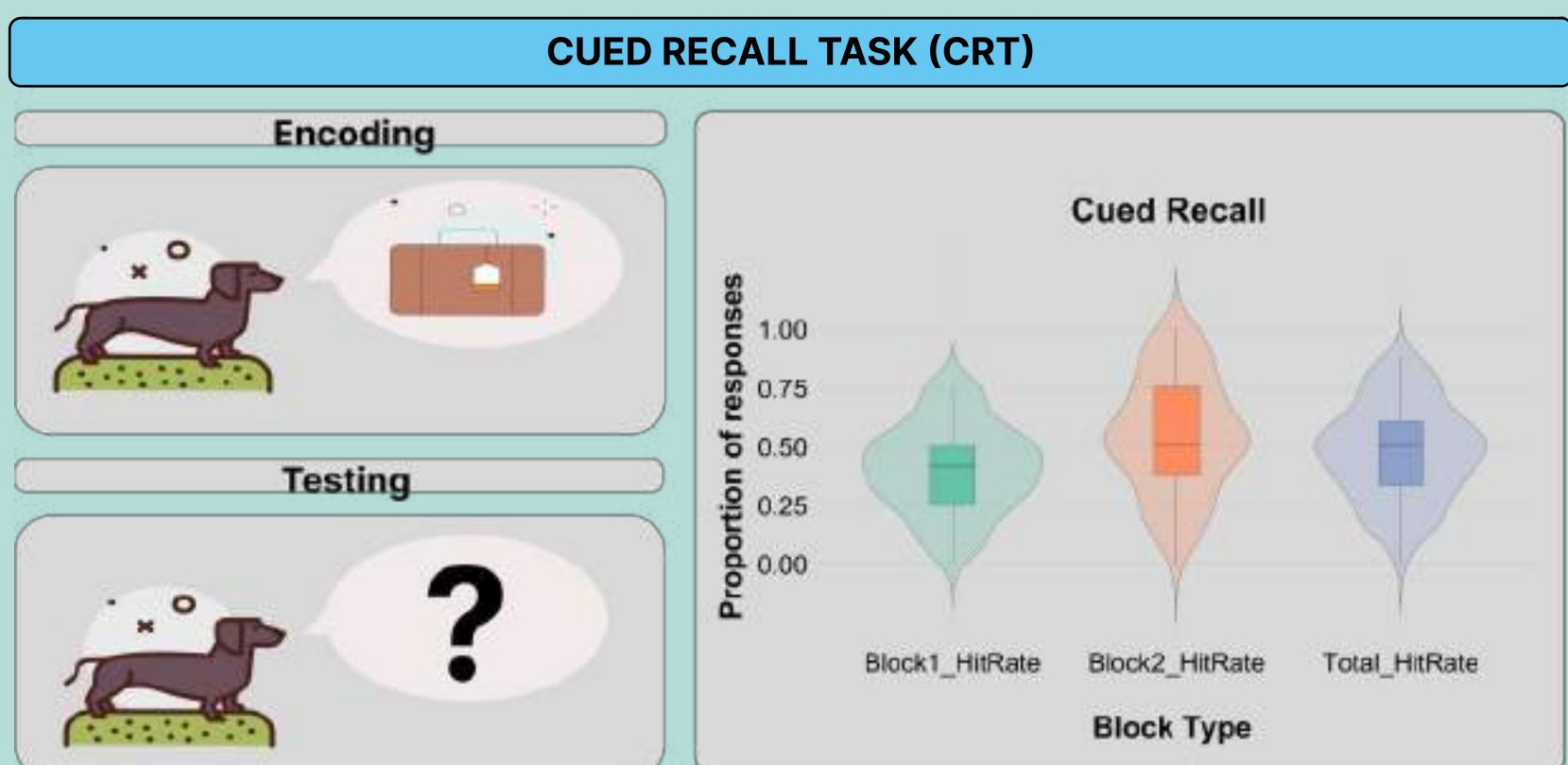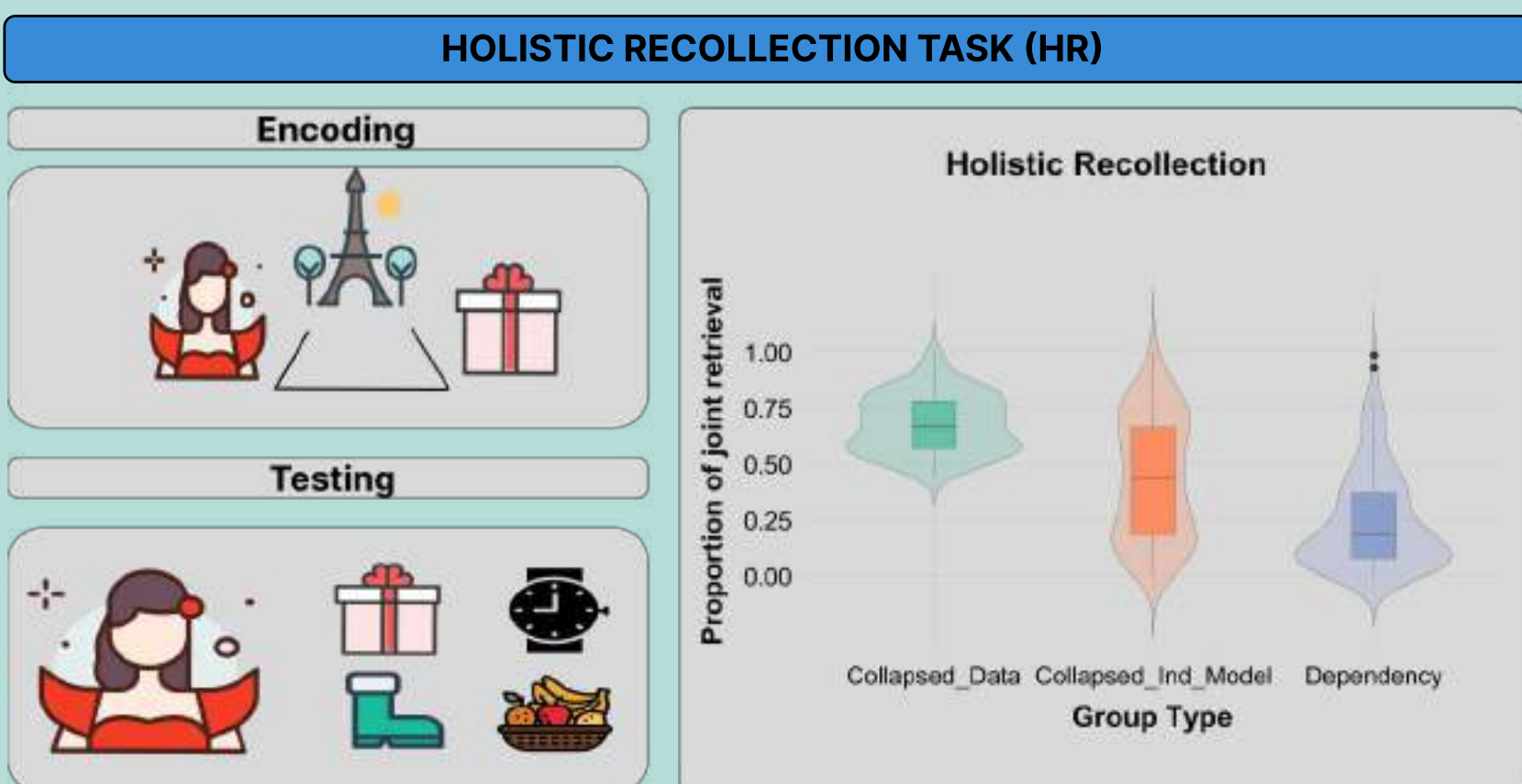
2. METHODS

- First wave of a 3-year longitudinal study of 4–6-year-old children.
- Participants: 131 four-year-olds (mean age = 54.2 months, SD = 3.02; 62 female).
- No direct task exists to measure Pattern Separation (PS) and Pattern Completion (PC) → modeled as latent variables using Structural Equation Modelling (SEM).
- Compared a two-factor PC–PS model with a one-factor memory model.
- Hippocampal segmentation from MRI scans was performed to examine neural correlates of task performance.
- Hypothesis: In 4-year-old children, a latent memory structure can be identified, with a two-factor model providing a better explanation of individual differences than a one-factor model.
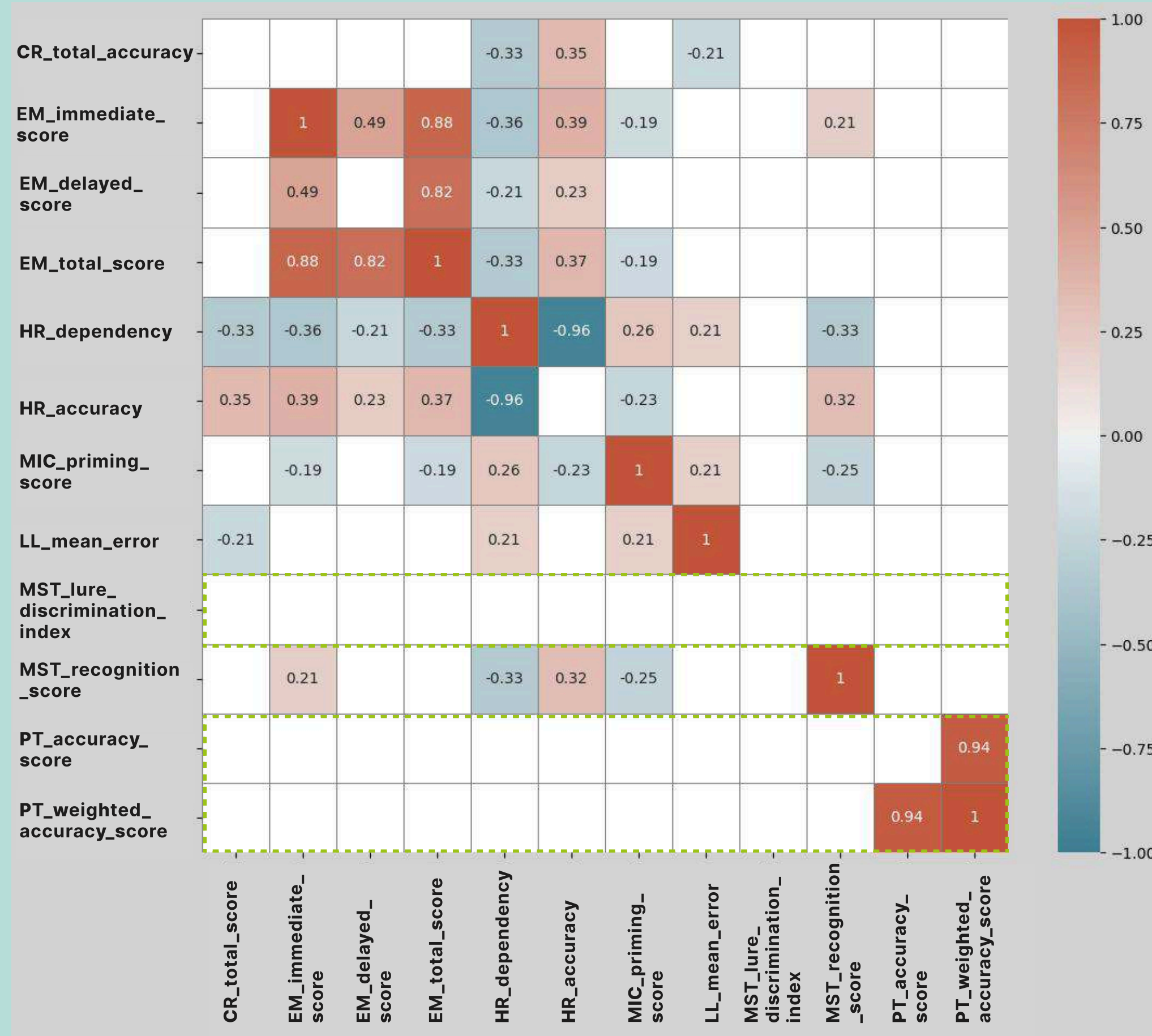
3. TASK BATTERY AND RESULTS

Pattern separation tasks and results

MNEMONIC SIMILARITY TASK (MST)
Encoding
Testing
'OLD'   'SIMILAR'   'NEW'

MST response proportions

LOCATION LEARNING TASK (LLT)
Encoding
Testing

Location Learning Error Rate/Delay Block

PRIMACY TASK (PT)
Encoding
Testing

Primacy Response Proportions/ Distance Category

*due to no significant correlation with other tasks, PT is not included in the model

EVENT MEMORY TASK (EM)
S1: Encoding → Free Recall → Prompted Recall
S2: Free Recall → Prompted Recall

Event Memory Response Proportions/ Story Type

Pattern completion tasks and results

HOLISTIC RECOLLECTION TASK (HR)
Encoding
Testing

Holistic Recollection

CUED RECALL TASK (CRT)
Encoding
Testing

Cued Recall

MEMORY IMAGE COMPLETION TASK (MIC)
Encoding + Testing

Memory Image Completion

4. TASK CORRELATIONS


Variable Selection and Factor Structure
Based on the correlation matrix, none of the Primacy Task (PT) variables correlated significantly with other indicators and were excluded. For the Holistic Recollection Task, we retained the primary variable (HR_dependency). In the Mnemonic Similarity Task, the primary variable (MST_lure_discrimination_index) showed no significant correlations; therefore, we used the secondary measure (MST_recognition_score).
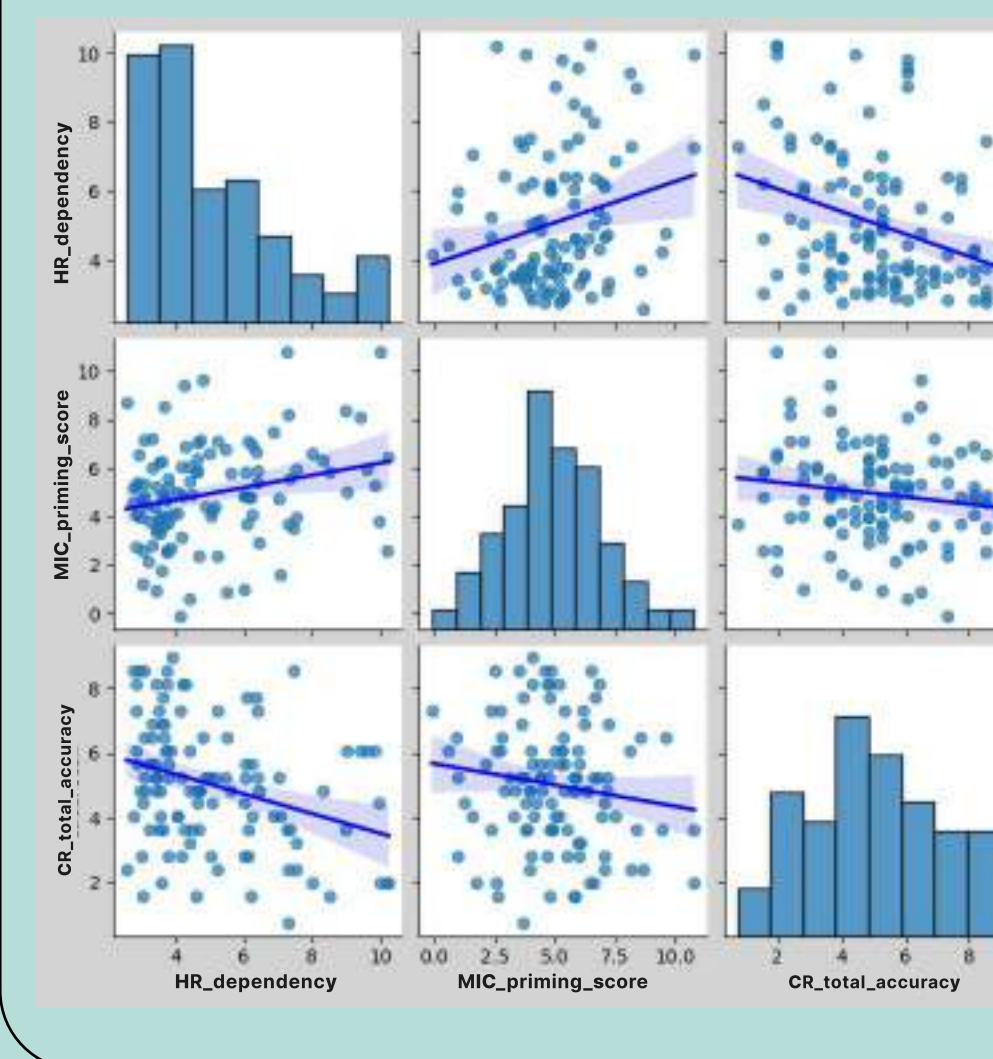
The resulting two-factor structure was:
PS ← LLT (loclearning), MST (mst_rr), EM (em_total)
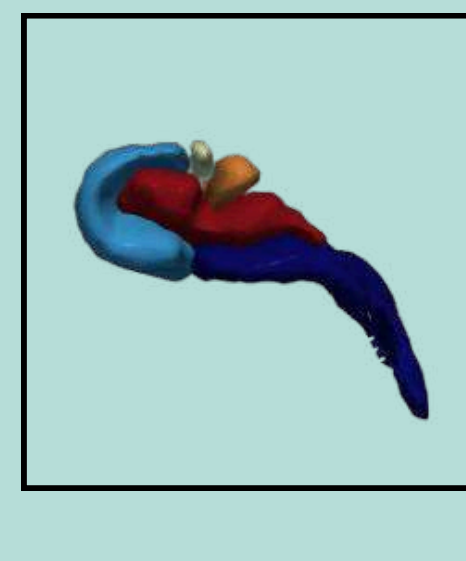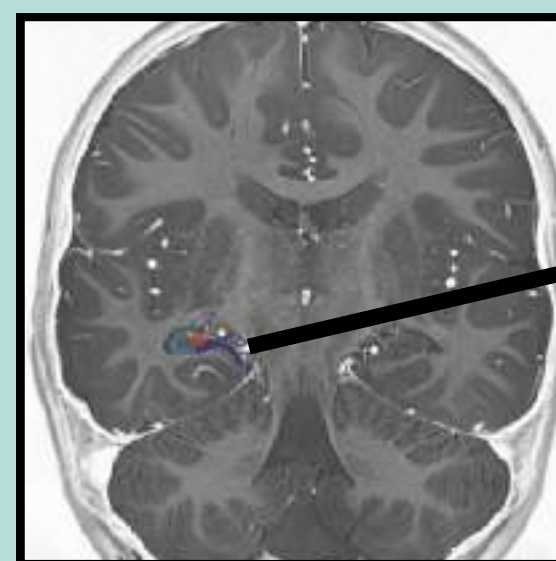PC ← MIC (mic), HR (holrec_dep), CR (cuedrecall)

PS factor
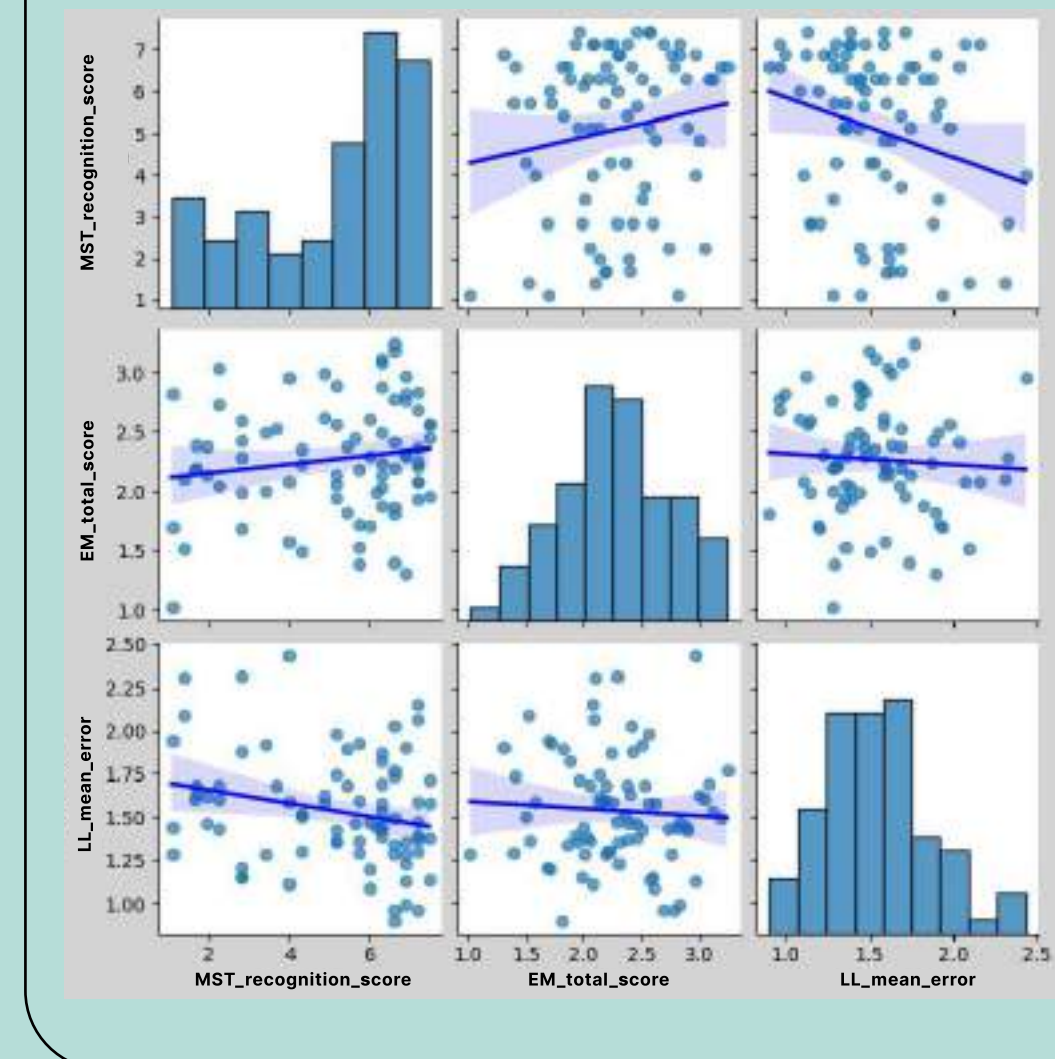
PC factor

5. HIPPOCAMPAL SEGMENTATION PROGRESS

- Subiculum
- Cornu Ammonis 1
- Cornu Ammonis 2
- Cornu Ammonis 3
- Dentate Gyrus

Manual and automated segmentation of high-resolution PD images (0.4×0.4×2 mm)
- Longitudinal analyses of target subfields changes using latent change score model
- Ongoing development of a child HC atlas, separating CA1–CA3–DG [5] (for more information check poster T41.)

Using our previous atlas, we observed significant correlations between subfield volumes and cognitive measures:

6. STUCTURAL EQUATION MODELLING

two-factor PC-PS model

PC: CRT, MIC, HR
PS: LLT, EM, MST
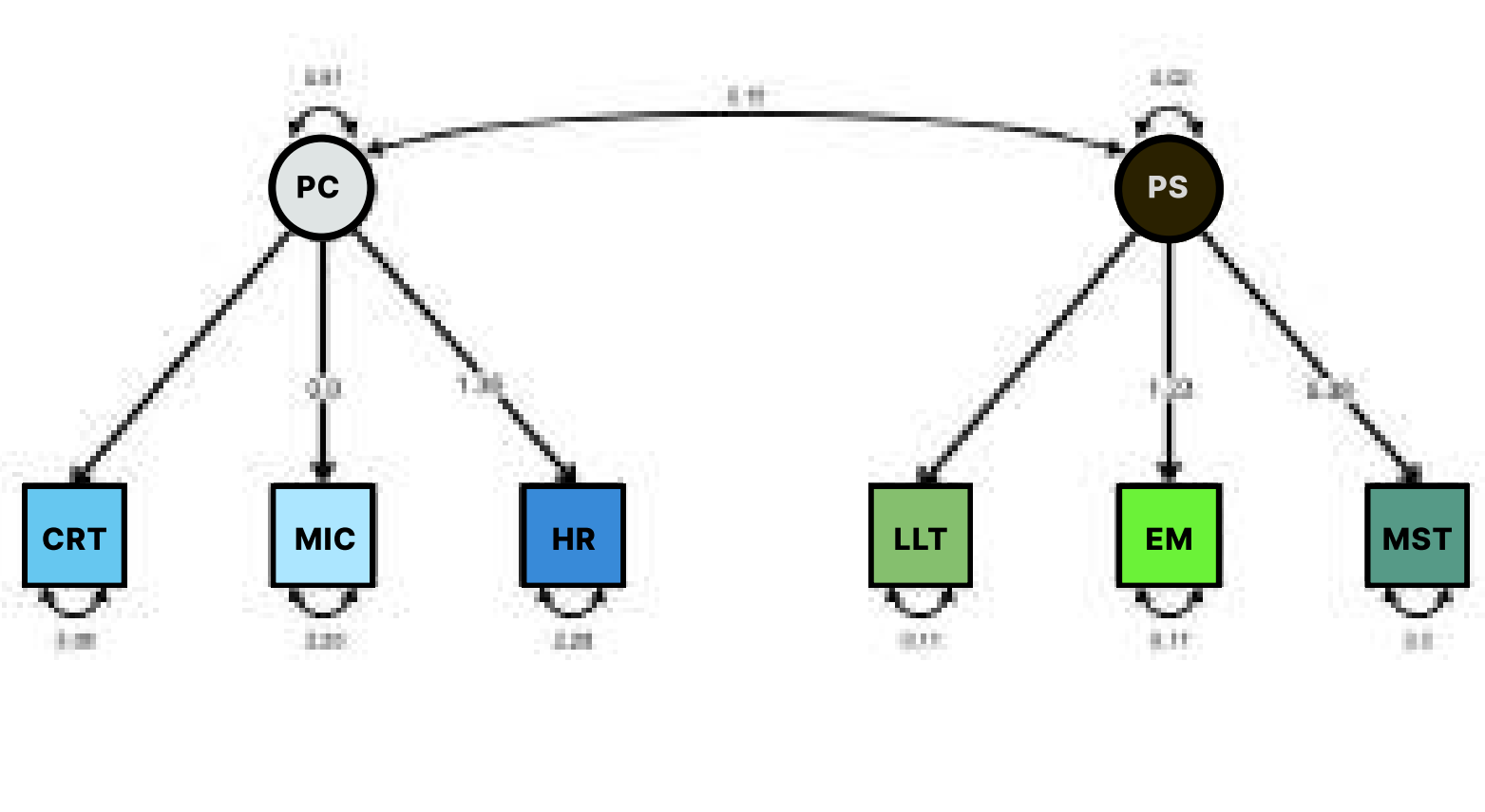
Model Fit parameters: CFI = 1.058; RMSEA =0.00

one-factor memory model

MEM: CRT, MIC, HR, LLT, EM, MST
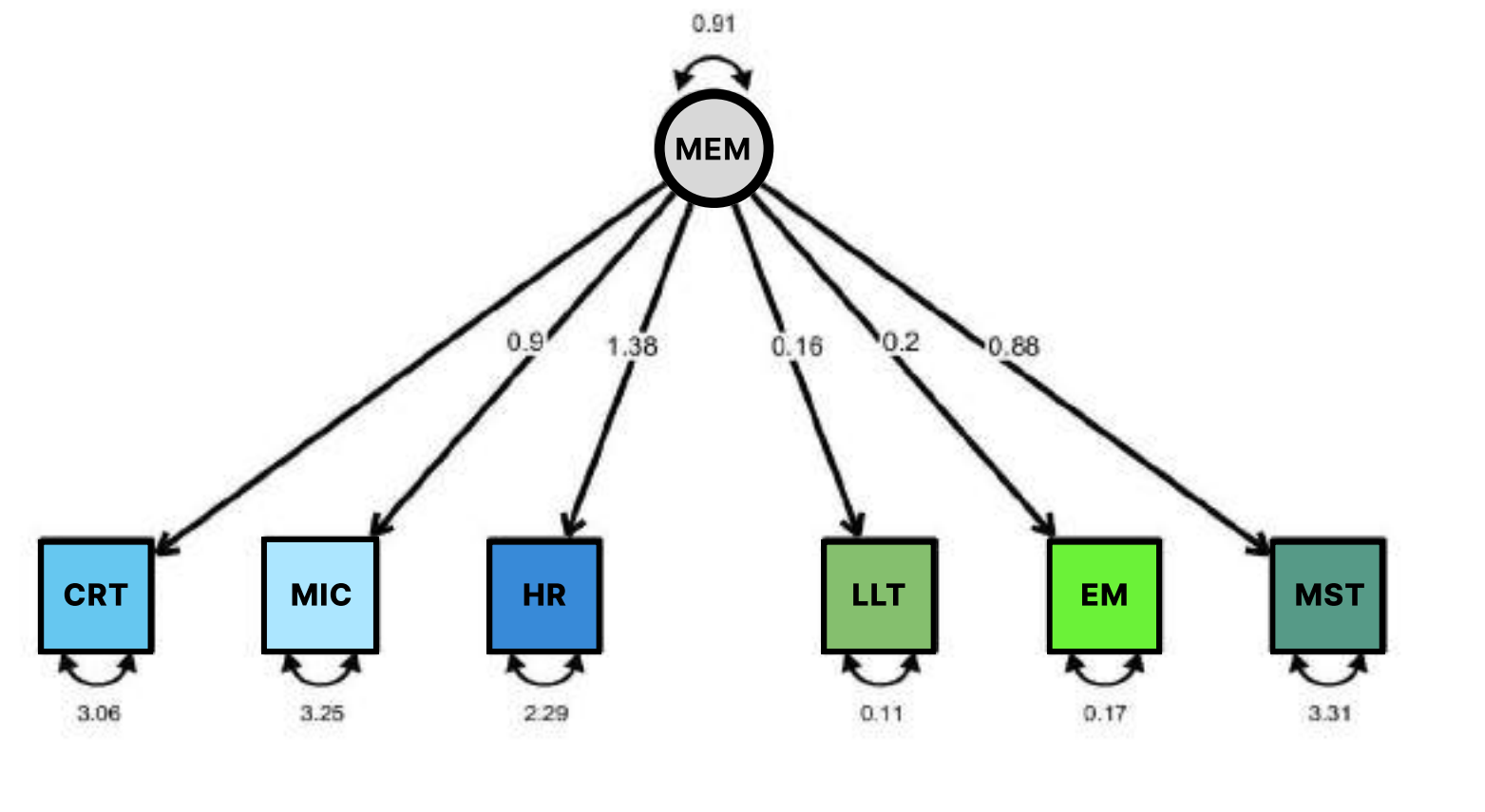
Model Fit parameters: CFI = 1.08; RMSEA =0.00

Key Findings: 1. Both the one-factor and two-factor models showed excellent fit to the data based on CFI and RMSEA values, which were above the recommended cutoffs.
2. The Chi-square difference test was used to compare the nested models. The one-factor model demonstrated a significantly better fit ($\chi2$ (1)=16.856; p<0.001), indicating it is the statistically preferred model.

7. DISCUSSION

1. The findings suggest that memory-related computations may potentially be assessed in 4-year-old children using a latent variable modeling approach.

2. Both the two-factor PC–PS model and the one-factor memory model fit the data; however, Chi-square comparisons indicated that the one-factor memory model provides the best fit.

3. Preliminary hippocampal segmentation analyses further suggest a potential link between behavioral performance and hippocampal subfield volume.

8. References

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