Temporal memory organization across different time spans in the macaque

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Abstract

Objective Temporal order memory is a critical component of episodic memory. We looked into temporal memory across extended timeframes and multiple sessions. **Methods** We conducted three-day Time Order Judgment (TOJ) tasks with one rhesus monkey. On Days 1-2, the monkey encoded four videos (each with two clips), learning each video 15 times, followed by TOJ testing on all encoded clips. On Day 3, a TOJ test using all possible image pairs from the 16 previously encoded clips assessed long-term memory using image pairs from all 16 previously encoded clips (120 pairwise combinations) . Bayesian hierarchical modeling analyzed the effects of boundary types (within-video, across-video, across-day) and temporal distance (TD, 1-15) on memory accuracy. **Results** The monkey demonstrated above-chance TOJ accuracy (68.52%, 3840 trials). Bayesian hierarchical analysis revealed that boundary type significantly influenced memory performance after controlling for temporal distance: Boundary types were defined as: within-video (clips from the same video), across-video (clips from different videos within the same day), and across-day (clips from different days). The model used dummy variables for all three boundary types, with each β coefficient representing the absolute contribution of that boundary type to logit (accuracy) relative to the model baseline (intercept + interval effect). Boundary type effects on memory accuracy showed: within-video boundaries significantly improved performance (β=0.667, 95% HDI:[0.174, 1.154]), across-video boundaries had a moderate positive effect (β=0.157, 75% posterior probability of positive effect), while across-day boundaries significantly impaired performance (β=-0.767, HDI:[-1.259, -0.284]). The pairwise effect size differences between boundary types showed statistically reliable separation (within-video vs across-video: 0.510; across-video vs across-day: 0.924). **Neurophysiological Analysis**: Single-unit recordings from 41 neurons during Day 3 testing revealed significant neural-behavioral coupling. Using representational similarity analysis with Mantel tests, we found that 17/41 neurons (41%) showed significant correlations between neural firing patterns and behavioral reaction time patterns ($p < 0.05$). Five neurons demonstrated medium effect sizes ($r > 0.3$), with the strongest correlation reaching $r = 0.437$ ($p < 0.001$). Notably, neural activity patterns correlated more strongly with reaction time similarity structures than with accuracy patterns, suggesting these neurons encode decision processes rather than memory outcomes. **Conclusion** These results demonstrate that temporal memory exhibits hierarchical organization based on contextual boundaries, supported by both behavioral performance and underlying neural representations. Neural activity patterns in mPPC selectively encode the temporal dynamics of memory retrieval rather than accuracy outcomes, providing neurophysiological evidence for the computational processes underlying structured temporal memory organization in non-human primates.

Keywords: Temporal memory, temporal order judgment, Mantel Test, Bayesian modeling

Method

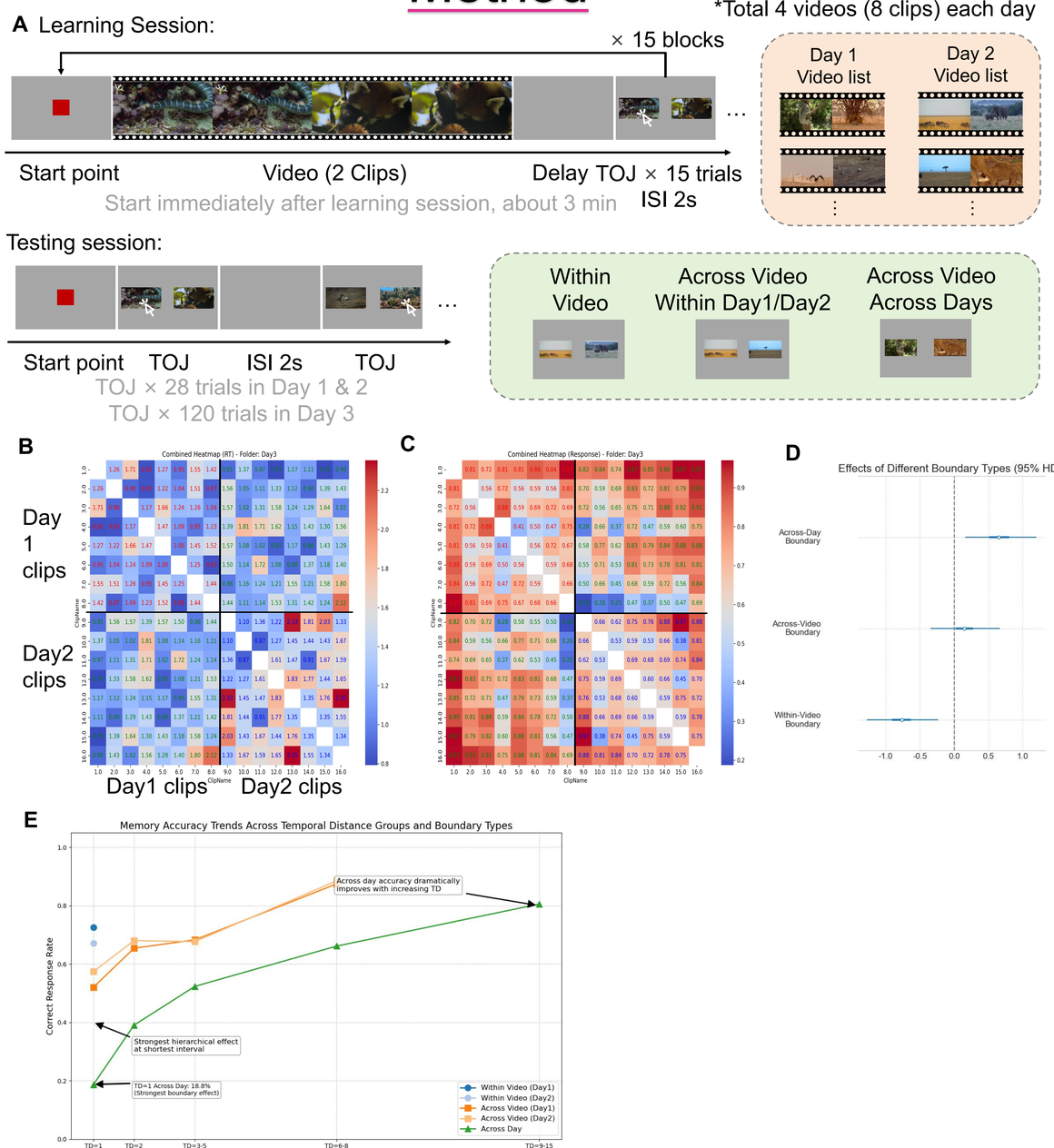
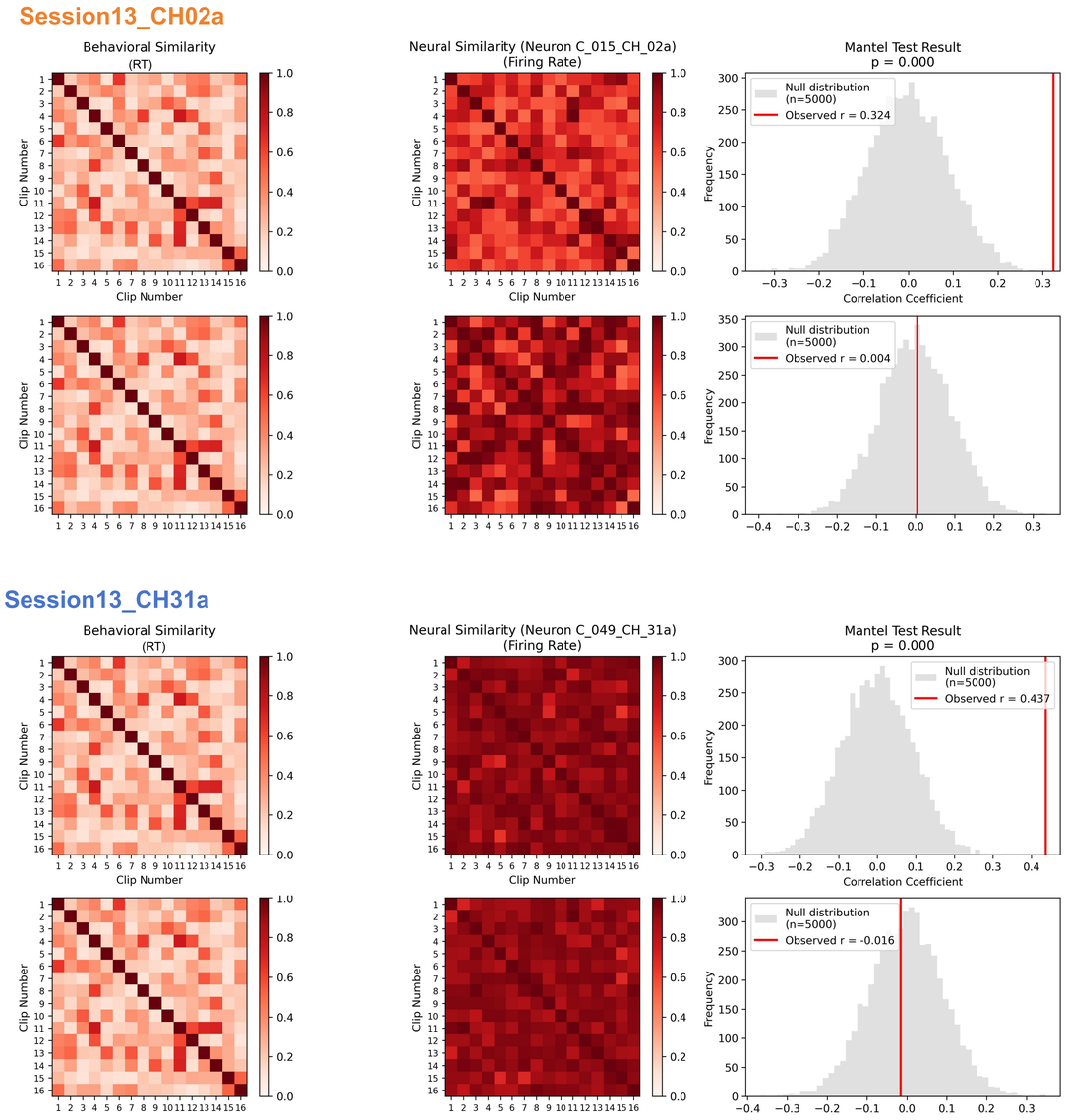


Figure 1. **Experimental design and behavioral results**. (A) Three-day temporal order judgment paradigm. Days 1-2: Learning phase with 4 videos (8 clips) per day, followed by within-day testing. Day 3: Comprehensive testing with all possible clip pairs (120 combinations). (B-C) Behavioral performance matrices showing accuracy for Day 1 and Day 2 clip comparisons. (D) Boundary type effects on reaction time. (E) Memory accuracy trends across temporal distances and boundary types, demonstrating hierarchical organization (within-video > across-video > across-day).

Results

RT v.s. neural F/R multivariate correspondence(group level, 17/41)



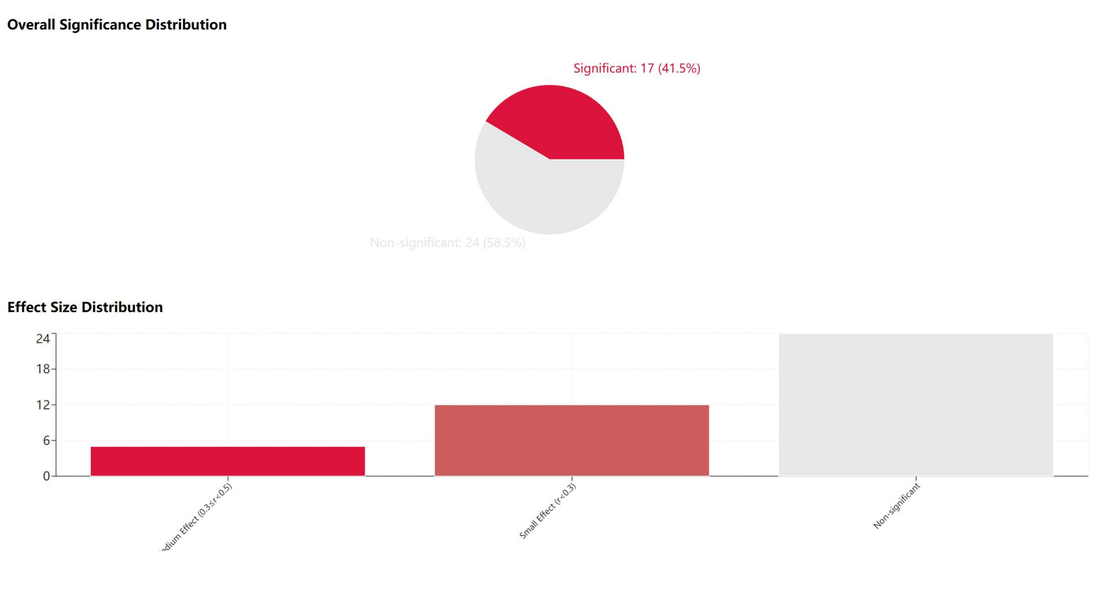


Figure 2. Neural-behavioral representational similarity analysis. Representative results from Session 13 showing (Top) Neuron C_015_CH_02a and (Bottom) Neuron C_049_CH_31a. **Left panels**: Behavioral similarity matrices based on reaction time patterns. **Middle panels**: Neural similarity matrices based on firing rate patterns. **Right panels**: Mantel test results showing null distributions (gray) and observed correlations (red line). Both neurons demonstrated significant positive correlations between neural and behavioral similarity structures ($r = 0.324$, $p < 0.001$ and $r = 0.437$, $p < 0.001$, respectively), indicating that firing patterns reflect temporal decision processes.

Highlights

- Neural Patterns of Cross-day Temporal Order Memory
- RT-Behavioral Coupling in Temporal Memory Retrieval