Prefrontal Reinstatement of Contextual Task Demand Is Mediated by Separable Hippocampal Patterns

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Background

Task-set defines task-relevant and -irrelevant features, and guides cognitive control to adjust neural information processing in order to achieve adaptive behavior.

We live in a highly auto-correlated world, with predictable task demands that can be used to facilitate task performance. Previous studies demonstrate that (1) humans adjust behavior using temporal prediction of task demand[1, 2], and (2) dorsal striatum is involved in predicting task demand using temporal information[2, 3] (e.g., previous experienced tasks).

However, it is unknown (1) **whether task demand can be learned and predicted from associative memory** and (2) **whether and how the hippocampus contributes to retrieving task demand**.

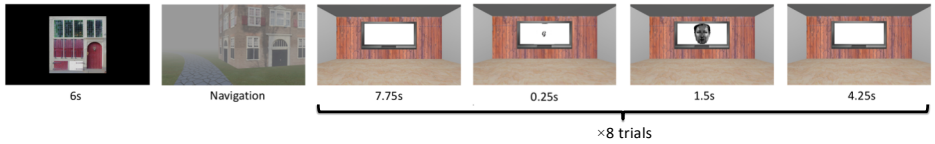
To answer these questions, we embedded a **cued perceptual decision making task** in **spatial contexts presented in an immersive environment.** Data were analyzed using **reinforcement learning** and **multivariate pattern analysis.**

Hypotheses:

(1) **Context-task demand associations can be learned to guide behavior.**

(2) **Hippocampal activity patterns of spatial contexts modulate cortical reinstatement of contextual task demand (CTD).**

Methods (N=33)



At the start of each block, participants were cued to navigate to a context/building in a 3D environment. After entering the context, participants categorized either the face or the object of a compound stimulus based on a task pre-cue. The proportion of Face vs. Object task trials created different contextual task demand based on the manipulations below.

Perceptual categorization based on task pre-cue.

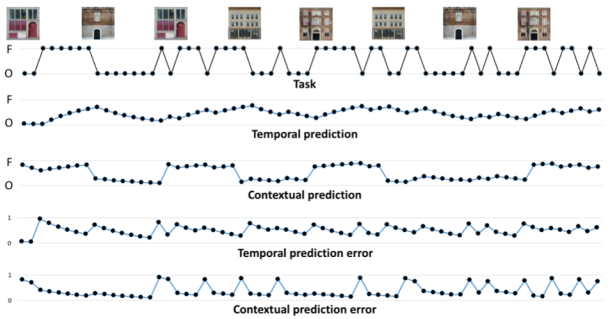
75% face task/25% object task

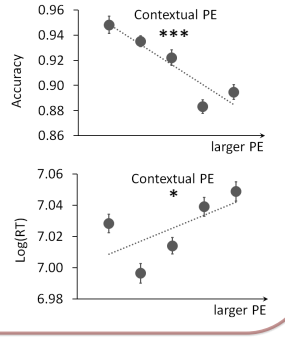
25% face task/75% object task

Context-task demand associations created by different proportions of Face task vs. Object task trials performed within one of four virtual contexts.

Results

Larger prediction errors of CTD were associated with more errors and slower responses



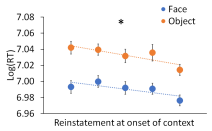


Reinstatement of CTD in dlPFC

Upon entering a context, activity pattern in dorsolateral prefrontal cortex (dlPFC, BA 9-46d) was more similar to the activity pattern of the predicted task than to that of the unpredicted task, suggesting reinstatement of CTD.

The context-trial pattern similarity in dlPFC predicted trial-level response time.

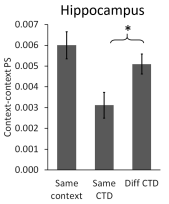
Context-trial pattern similarity, con > inc

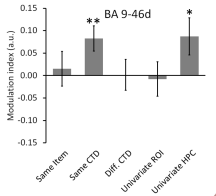


Hippocampal modulation of reinstatement of CTD

Hippocampal pattern similarity between contexts was lower for contexts sharing same CTD than contexts associated with different CTD (i.e., differentiation)[4].

Lower hippocampal differentiation lead to stronger CTD reinstatement in dlPFC, possibly due to recurrent input to hippocampus to retrieve associated CTD.





CTD: contextual task demand. *: P < 0.05; **: P < 0.01; ***: P < 0.001

Summary

1. Humans use spatial contexts to predict task demand and guide behavior accordingly.
2. Entering a spatial context triggers the reinstatement of its associated CTD in prefrontal cortex.
3. The degree of prefrontal reinstatement of CTD is mediated by distinctiveness of hippocampal patterns for spatial contexts.

References 1. Waskom et al., 2017; 2. Jiang et al., 2018; 3. Jiang et al., 2015; 4. Favila et al., 2016.

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