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# Consolidation Promotes the Emergence of Representational Overlap in the Hippocampus and Medial Prefrontal Cortex

## Highlights

- Patterns in mPFC and hippocampus represent featural overlap across remote memories
- Hippocampal encoding patterns are reinstated during remote retrieval
- Reinstatement is inversely related to the representation of overlap in hippocampus
- Encoding-related changes in functional connectivity relate to measures of overlap

## Authors

Alexa Tompary, Lila Davachi

## Correspondence

lila.davachi@nyu.edu

## In Brief

Using functional MRI in humans, Tompary et al. track time-dependent representational changes across overlapping and non-overlapping episodic memories. The authors demonstrate that neural patterns of memories in mPFC and hippocampus become restructured over time to represent overlap across memories.

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# Consolidation Promotes the Emergence of Representational Overlap in the Hippocampus and Medial Prefrontal Cortex

Alexa Tompary[1] and Lila Davachi[1,2,3,*]
[1]Department of Psychology
[2]Center for Neural Science
New York University, New York, NY, 10003, USA
[3]Lead Contact
*Correspondence: lila.davachi@nyu.edu
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## SUMMARY

**Structured knowledge is thought to form, in part, through the extraction and representation of regularities across overlapping experiences. However, little is known about how consolidation processes may transform novel episodic memories to reflect such regularities. In a multi-day fMRI study, participants encoded trial-unique associations that shared features with other trials. Multi-variate pattern analyses were used to measure neural similarity across overlapping and non-overlapping memories during immediate and 1-week retrieval of these associations. We found that neural patterns in the hippocampus and medial prefrontal cortex represented the featural overlap across memories, but only after a week. Furthermore, after a week, the strength of a memory's unique episodic reinstatement during retrieval was inversely related to its representation of overlap, suggesting a trade-off between the integration of related memories and recovery of episodic details. These findings suggest that consolidation-related changes in neural representations support the gradual organization of discrete episodes into structured knowledge.**

## INTRODUCTION

Our semantic knowledge is a highly structured network of associations that are, at least in some part, learned through the extraction and consolidation of common features across many episodic experiences. However, our understanding of how memories of discrete episodic events are transformed into structured information over time is crude at best. From a neuroscientific perspective, successful episodic memory retrieval is thought to be initially supported by the hippocampus, but then may gradually be supported by distributed cortical regions through incremental, coordinated reactivation of memories across the hippocampus and cortex (Alvarez and Squire, 1994; Nadel et al., 2000). Evidence for such a mechanism has been explored in rodent replay studies (Pavlides and Winson, 1989; Wilson and McNaughton, 1994) and in human neuroimaging research, by measuring how changes in resting-state connectivity after new learning relate to later memory (Tambini et al., 2010; Tambini and Davachi, 2013; Schlichting and Preston, 2014; Tompary et al., 2015). Such hippocampal-cortical dialog has been hypothesized to enable the slow extraction of statistical regularities common across overlapping episodic events (McClelland et al., 1995). However, how this process transforms the neural traces of episodic memories over the course of consolidation remains unknown.

Behavioral research in rodents and in humans provides compelling evidence that the structure of episodic memories changes with time. In a recent experiment, rodents learned a set of platform locations that were sampled from a predetermined distribution of locations. After 1 day, the animals tended to navigate to specific platform locations, but after 30 days, their swim patterns more closely matched the underlying probability distribution of all platform locations (Richards et al., 2014). Prior work has also shown that rodents begin to generalize context-specific behaviors to novel environments with time (Wiltgen and Silva, 2007). These findings suggest that recent memories are composed of distinct episodes, but remote memories become transformed and integrated into more generalized representations of related information. In humans, behavioral work has shown that rule acquisition and use is more evident with a temporal delay (Sweegers and Talamini, 2014). Similarly, other work suggests that sleep enhances transitive inference behavior (Ellenbogen et al., 2007; Lau et al., 2010) and benefits the extraction and generalization of statistical regularities across motor and acoustic patterns (Wagner et al., 2004; Durrant et al., 2011, 2013; Batterink and Paller, 2017). However, few studies to date have shed light on how the underlying neural representations of memories with shared features are transformed over time. In the present study, we examined whether neural representations of memories with overlapping features become more similar after a period of consolidation.

There is evidence that the medial prefrontal cortex (mPFC) likely plays an important role in the transformation of episodic memories over time, given its established involvement in two distinct mnemonic processes: retrieval of consolidated