



Event boundaries shape memory formation: evidence from single neuron recordings in humans



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INTRODUCTION

Life memories are carved as discrete events ("episodes")1.

What is the very definition of "episode"? Specifically, what dictates the onset and offset of an event stored in memory remains elusive².

Building upon previous studies³, we investigated the neuronal mechanisms that demarcate events by using behavioral measurements and single neuron recordings in humans.

EXPERIMENTAL SETUP Probe (self-paced) Clips with NB, SB and HB (~8s) e.g. Anyone wearing glasses? No Yes Clip Display [1-3] **NB** (no boundary) SB (soft boundary) **HB** (hard boundary) Virtual boundary happens at 4s Scene recognition 50% target 50% foil Confidence level: Old New = Very Unsure Frame [1-3] 2 = Less Sure Fixation (0.5s) Image display (1.5s) Probe (up to 5s) Temporal discrimination Frames across NB, SB or HB Which frame happens first? **Right Frame B** [1-3] Image display (2s) Fixation (0.5s) Probe (up to 5s) Single neuron recordings from 20 subjects with drug-resistant epilepsy

Amygdala

(AMY): 169

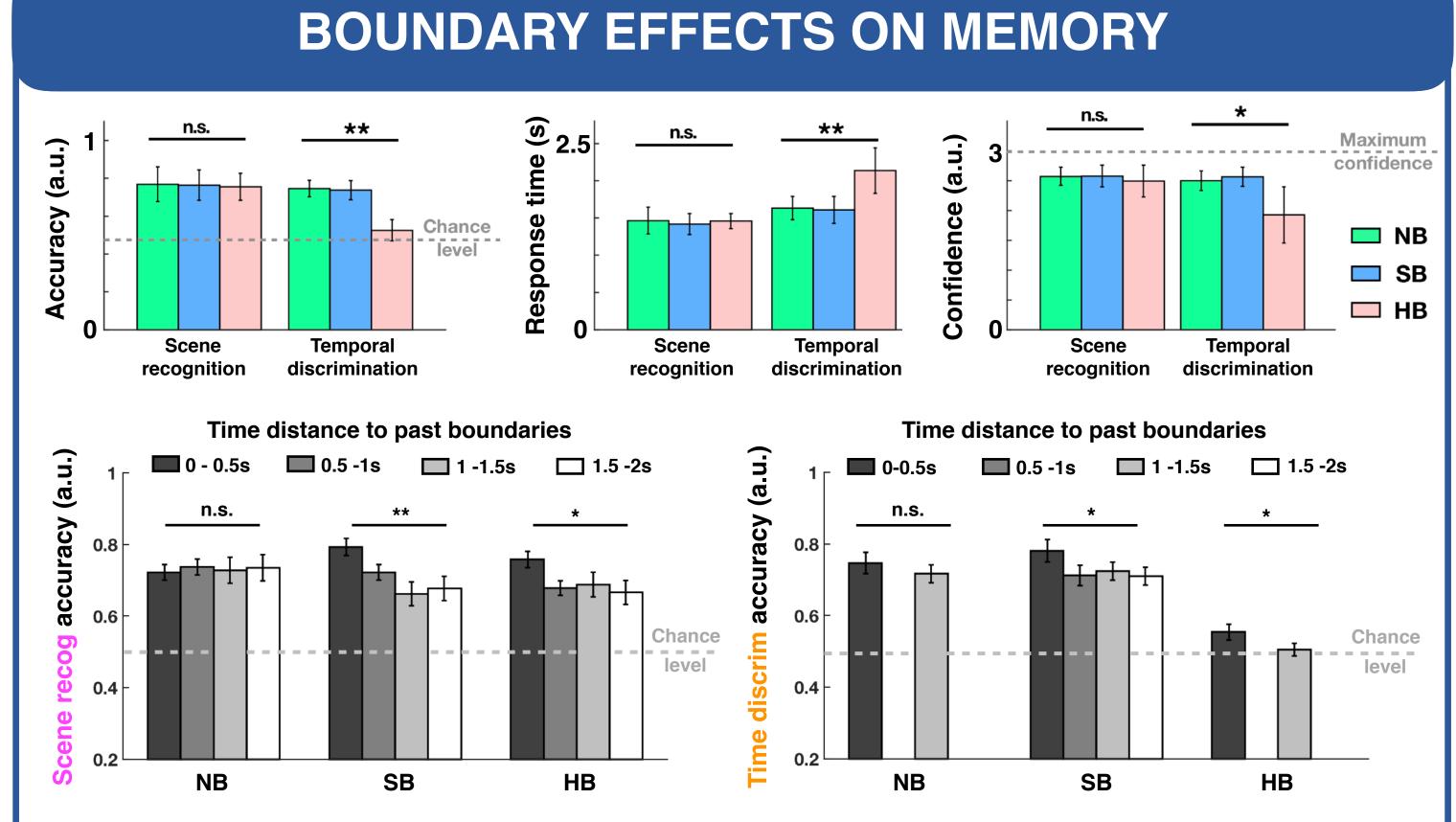
Medial temporal lobe (MTL)

Hippocampus

(HPC): 343

Parahippocampal gyrus

(PHG): 68



NEURONS SIGNALING DIFFERENT BOUNDARIES Responses of all B cells and E cells **Boundary cell (B cell) Event cell (E cell) Encoding Encoding** B cell, HB aligned E cell, aligned to boundaries aligned to boundaries E cell, SB aligned E cell, NB aligned Time (seconds) Time (seconds) Time (seconds) Normalized firing rate B cell with memory effect E cell with memory effect Latency between B cells and E cells (Bm cell) (Em cell) **Time discrimination Encoding** B cells aligned to responses E cells **Spatial distribution of B and E cells** B cells **Bm cells** E cells **Bm cells** 40 Time (ms) **0** 10 AMY HPC PHG OFC ACC MCC SMA INS Time (seconds) Time (seconds)

Mean trajectories during encoding (projected to the top 3 demixing PC space*) Neural state shifts during encoding (computed with different cell populations) All MTL cells No B cells No B cells No B and E cells No B and E cells No B and E cells No B cells No B and E cells No B cells

CONCLUSIONS

Behaviorally, boundaries enhance the scene recognition while HB impairs the recollection of the temporal order

78/580 putative neurons signaling boundaries in the MTL (B cells: n = 42, both SB and HB; E cells: n = 36, only HB)

Response strengths of Bm cells (n = 11) and Em cells (n = 16) correlate with subjects' memory performance in the scene recognition and the temporal discrimination, respectively

Neural state shifts present when crossing boundaries, coordinated by different neural populations (HB: all MTL cells; SB: mainly B cells)

Significant latency of neural state shifts exist among different neural populations when crossing HB, suggesting a hierarchical structure for event segmentation (B cells -> E cell -> unassigned MTL cells)

Neural state shifts introduce a memory "trade-off": with large neural state shifts enhance scene recognition but harm temporal discrimination

REFERENCES

Tulving, E., 2002. Episodic memory: From mind to brain. Annual review of psychology.
 Ezzyat, Y. and Davachi, L., 2011. What constitutes an episode in episodic memory?. Psychological Science.
 Brunec, I.K., et al, 2018. Boundaries shape cognitive representations of spaces and events. Trends in Cognitive Sciences.
 Kobak, D., et al, 2016. Demixed principal component analysis of neural population data. Elife

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