Bidirectional hippocampal-cortical ripple dialogue during narrative generation and retrieval

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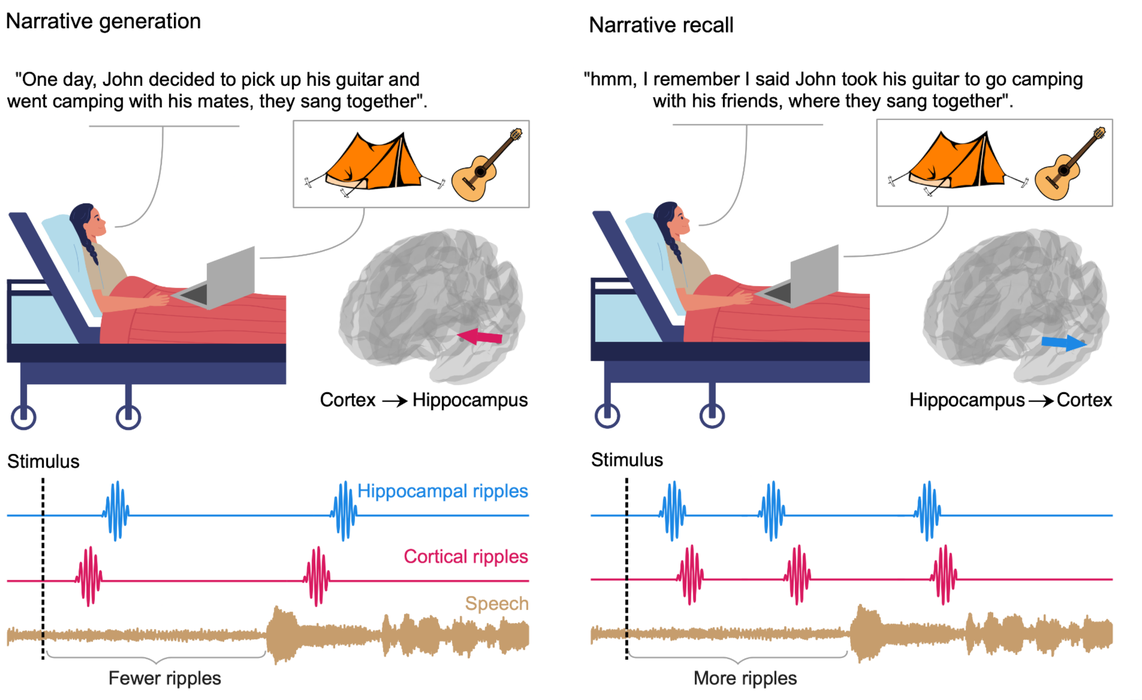
Summary

Humans utilize relational knowledge to generate and recall their conscious experiences, which encapsulate context, spatiotemporal sequences, and social interactions. Hippocampal sharp-wave ripples (SWRs) are especially critical for visual episodic retrieval and events replay, while the lateral temporal cortex contributes to memory selection and semantic control. However, the specific involvement of human episodic and semantic memory processes remains poorly characterized.

In this study, we recorded intracranial electroencephalography (iEEG) from epilepsy patients in the hippocampus and lateral temporal cortex (LTC) while they underwent narrative generation and memory retrieval. We discovered a highly process-specific ripple dialogue in the cortical-hippocampal circuitry. Temporal synchronization of ripples between regions revealed a bidirectional interplay of greater ripple flow for cortical-hippocampal during narrative generation, but a higher density for hippocampal-cortical ripple flow during memory retrieval. Our results characterize an undocumented ripple relationship subserving knowledge-based narrative generation versus memory retrieval. Separating these two processes will facilitate elucidating the neural mechanisms of semantic and episodic memory in the human brain.



Method

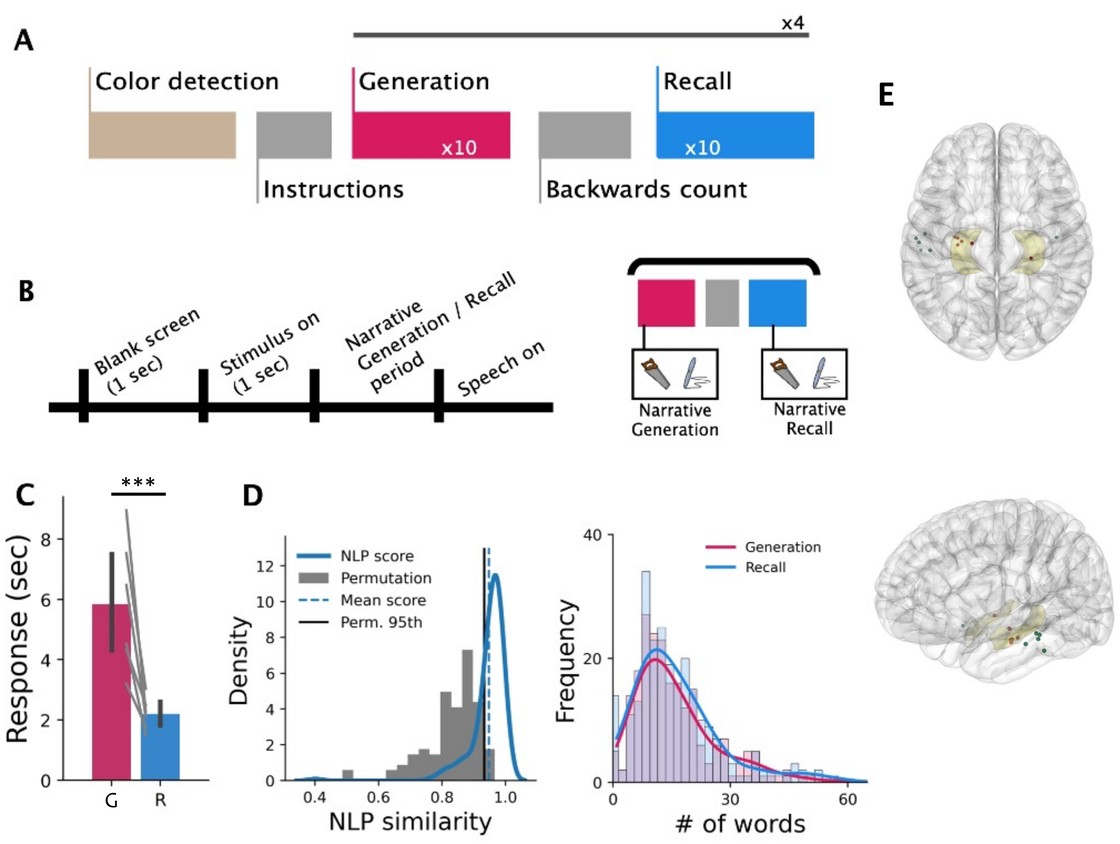


Figure 1. Experimental design, behavioral results and electrode placement sites.
(A) Experimental design. Subjects performed a color detection task before the main task began. The main experiment consists of 4 sessions, each session includes a narrative generation phase and a narrative recall phase, with 10 trials respectively.
(B) Trial structure. Participants were required to either generate a narrative involving the two presented items or recall the narrative created before when seeing the same item pairs.
(C) Response duration between stimulus onset and verbalization for generation (G) and Recall (R) trials. Each line denotes an individual participant. Error bars denote SEM.
(D) Distribution of natural language processing (NLP) similarity scoring between generation and recall trials and their respective permutation distributions, indicating that subjects reliably recalled the self-generated narrative content (left). Histogram showing the distribution of numbers of words for all trials for the two experimental conditions. The two distributions are not different from each other (right).
(E) Electrode placement for hippocampal (red) and lateral temporal cortical (green) sites for the 6 subjects.

Results

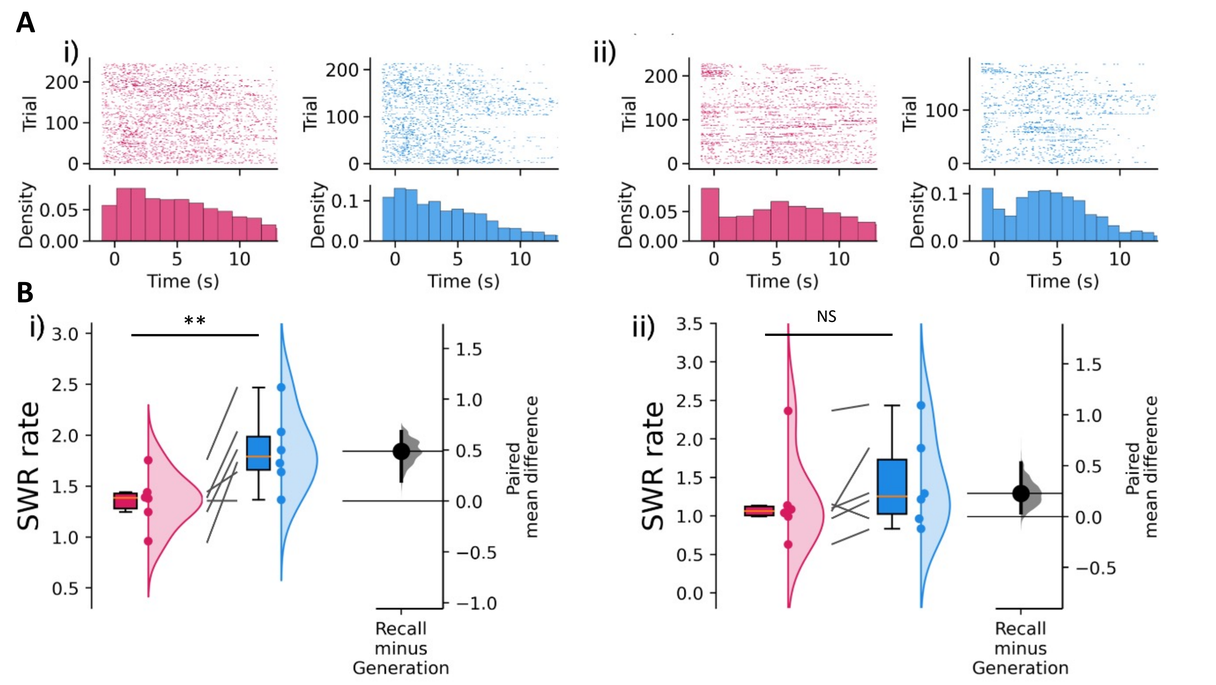


Figure 2. (A) Raster and density plots for the (i) hippocampal ripples and (ii) LTC ripples time-locked to stimuli onset for the narrative generation (in red) and recall (in blue) phases respectively. Trials were aggregated across participants. (B) Ripple rate (events/s): (i) Hippocampal ripple rate is higher during recall trials (1.85 ± 0.34) compared with generation trials (1.36 ± 0.24; t = -3.76, p = 0.01). (ii) No statistical differences were found for the LTC electrodes (Generation 1.20 ± 0.54; Recall 1.44 ± 0.56; t = -1.67, p = 0.10).

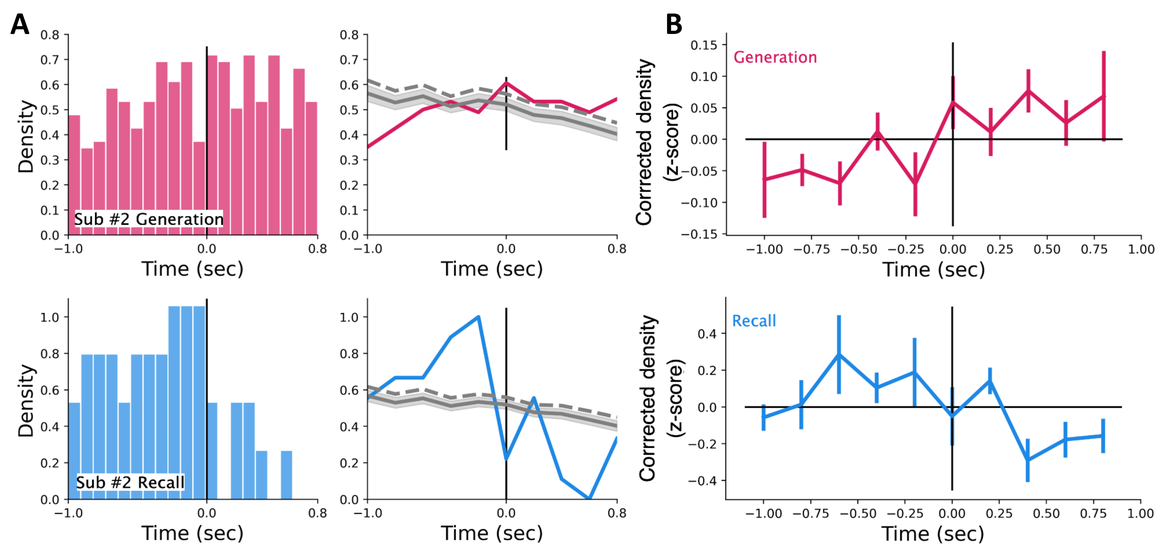


Figure 3. (A) Hippocampal-referenced ripple lag distribution for narrative generation (top) and recall (bottom) phases from subject 2. Zero corresponds to hippocampal-LTC ripple co-occurrence; negative bins indicate hippocampal ripples precede LTC, and positive bins indicate the opposite. Shift-predictor mean (solid grey line), and corresponding 99th percentile (dashed line) are shown. (B) Shift-predictor normalized ripple lag distribution at Group-level in narrative generation (top) and recall (bottom) conditions. The upwards and downwards density trends suggest directionally-specific ripple dialogue between the two regions. (C) Slopes (r scores) from shift-predictor normalized ripple lag (panel B) showed a significant difference between generation and recall. (D) Statistically significant time bins in the ripple cross-correlogram. (i) the six patients are displayed as separate lines. (ii) the group statistics for the cross-correlogram strength (a.u.) for the six patients are shown for the two experimental conditions. In the generation condition (top), stronger LTC → hippocampal correlation suggests LTC ripples precede hippocampal ones. In recall (bottom), stronger hippocampal → LTC correlation indicates hippocampal ripples precede LTC ripples. Red and blue plots denote narrative generation and narrative recall phases respectively.

Highlights

- Ripple events detected during the generation and recall of semantic narratives
- Hippocampal → LTC ripple dialogue underpins declarative memory recall
- LTC → hippocampal ripple dialogue during narrative generation

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