Deterministic search process underlies memory recall

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MOTIVATIONS

- Humans exhibit remarkable proficiency in reciting poems, participating in performances and giving long talks;
- Recalling a collection of unrelated events is challenging.

To understand human memory one needs to understand both the ability to acquire vast amounts of information and at the same time the limited ability to recall random material.

Free recall

Author
Valley
Bubble
Creature
...
...
Iron

→ Recall as many word as possible, in any order

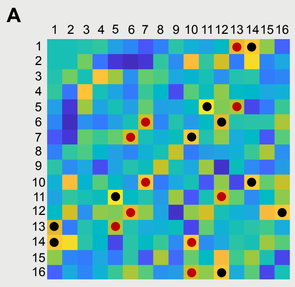
THE MODEL

1. Memory items are represented in the brain by sparse neuronal ensembles in dedicated memory networks.

$$\xi_i^\mu = (0;1) \quad \begin{cases} i = 1,\dots,N \\ \mu = 1,\dots,L \end{cases} \longrightarrow \quad P(\xi_i^\mu = 1) = f \ll 1$$

2. Recall of subsequent items is triggered by the largest overlap between item representations.

$$S_{\mu,\nu} = \sum_{i=1}^{N} \xi_i^\mu \xi_i^\nu$$

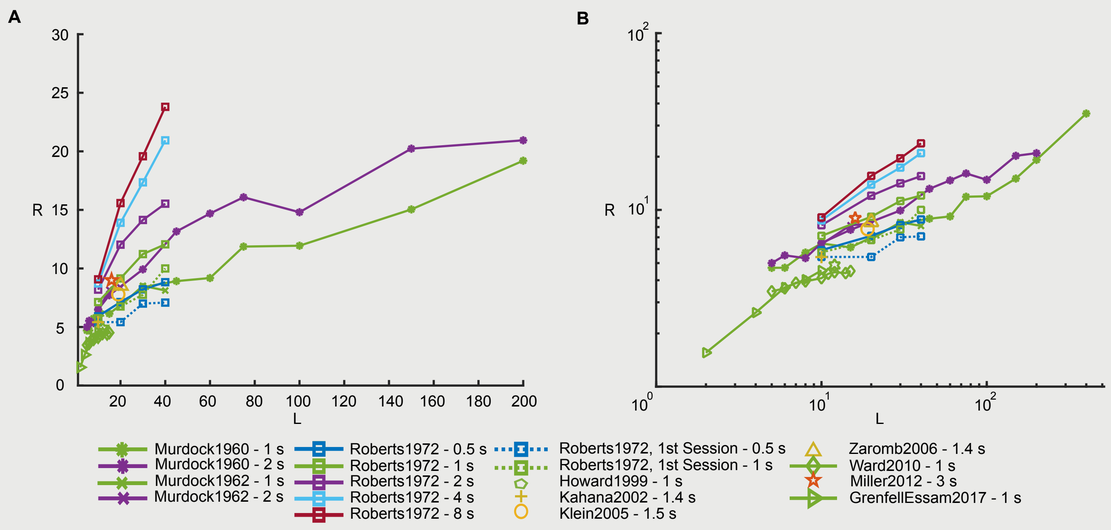


$$R = \sqrt{\frac{3}{2}\pi L}$$

Words recalled — Words presented

EXPERIMENTAL OBSERVATION AND HYPOTHESIS

Data are collected from 10 publications. Each color corresponds to same presentation time, whereas each marker corresponds to the publication the data were taken from.



Hypothesis: Differences in acquisition is the main cause of variability in published studies

$$R = \sqrt{\frac{3}{2}\pi L} \longrightarrow R = \sqrt{\frac{3}{2}\pi M}$$

Words recalled — Words acquired

EXPERIMENTAL DESIGN

726 participants were recruited to perform memory experiments on Amazon Mechanical Turk. The set of list lengths was: **8, 16, 32, 64, 128, 256 or 512 words**. The presentation rate was 1.5 seconds per word.

Each participant performed the two experiments with lists of the same length.

Free recall experiment → **R**

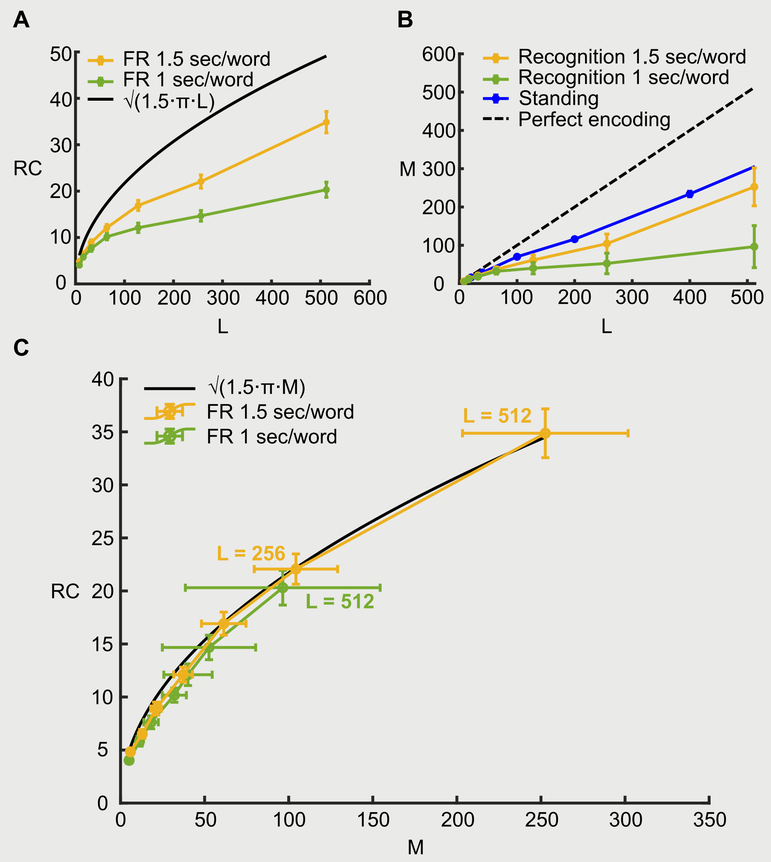
Recognition experiment → **M**

Author
Valley
Bubble
Creature
...
...
Iron

→ Creature / ? / Lure word

$$C = \frac{M}{L} + \frac{1}{2} \cdot \left(1 - \frac{M}{L}\right) \rightarrow M = L \cdot (2C - 1)$$

RESULTS



(A) Average number of words recalled as a function of the number of words presented. **(B)** Estimated average number of acquired words for lists of different lengths. Black dashed line corresponds to perfect encoding, yellow line corresponds to presentation rate 1.5 sec/word and green line to presentation rate 1 sec/word. Blue line corresponds to the results of Standing. **(C)** Average number of words recalled as a function of the average number of acquired words. Black line: theoretical prediction. Yellow line: experimental results for presentation rate 1.5 sec/word. Green line: experimental results for presentation rate 1 sec/word.

CONLUSIONS

- Acquisition stage of recall experiments is variable;
- The recall of the encoded information is governed by the stereotyped process.

Conclusions: We conclude that human memory recall operates according to deterministic search process, which results in a fundamental limit on the number of items that can be successfully recalled.

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