

Direct Brain Interfaces for Memory Restoration

Daniel S. Rizzuto, PhD

Introduction

Human episodic memory encoding fluctuates in its efficiency from moment to moment, leading to variability in the ability to store information for later retrieval. Oscillatory brain activity both during and prior to an event predicts later memory, suggesting that direct manipulation of brain activity through stimulation could be used to modulate memory function. Prior work from our team used open-loop neurostimulation to modulate memory encoding and we found that the effect of stimulation was dependent on the state of the brain prior to stimulation delivery (Ezzyat et al. 2017). Stimulation applied during poor encoding states significantly increased memory performance, suggesting that stimulation might consistently increase memory function if timed to coincide with poor memory states. Here we present a direct test of this hypothesis using a closed-loop design.

Methods

Twenty five patients with intracranially implanted electrodes performed a free recall memory task. Closed-loop neurostimulation was delivered during poor encoding states in a variety of brain regions, with one region targeted per session. We used a subject-specific multivariate classifier trained on previous record-only electroencephalographic data to decode the probability of memory success for each item and triggered stimulation if the classifier indicated that later recall was unlikely.

Results

Stimulation significantly increased memory performance by nearly 15% relative to a matched non-stimulated control condition when applied to lateral temporal cortex (Fig. 1, blue bar; $p < 0.05$) while it significantly impaired performance when applied to other areas of the brain (Fig. 1, green bar; $p < 0.01$), including medial temporal lobe.

Conclusion

These data indicate that superficial cortical areas can be targeted to enhance memory performance using closed-loop neurostimulation. In addition, our results suggest that memory dysfunction can be treated using implanted devices.

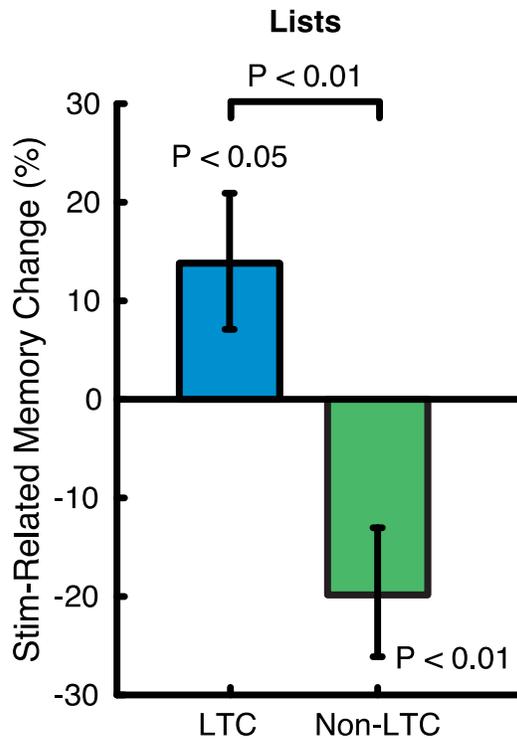


Figure 1: Direct brain stimulation increased recall performance when applied to lateral temporal cortex sites (blue bar) while it impaired recall performance when applied to other brain areas (green bar). Change in recall performance was calculated by comparing performance on stimulation lists with that of no-stimulation lists. Error bars represent standard error of the mean.

References

- Ezzyat et al. (2017) Direct brain stimulation modulates encoding states and memory performance in humans. *Current Biology*, 27, 1251–1258

Keywords

- Human
- Memory
- Brain stimulation
- Brain computer interface
- Neural prosthetics

Definitions

- **Multivariate classification:** A machine learning technique involving supervised learning of multiple data features to predict one or more classes.
- **Episodic memory:** Memory for autobiographical events that can be explicitly stated or recalled. For example, if one remembers the party on their 6th birthday, this is an episodic memory.
- **Brain oscillations:** Electrical activity summed across a large population of neurons synchronously firing together produces an oscillatory waveform that can be analyzed using spectral decomposition techniques.