

Microelectrode Recordings Using Depth Electrodes in Epileptic Patients:

A Systematic Review for Clinical and Cognitive Research

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Introduction

- Microelectrode recordings (MER) with depth electrodes have advanced understanding of human brain function
- Micro-macro specialized electrodes enable recording of single-/multi-unit activity, micro and macro LFPs
- Intracranial EEG in epilepsy patients provides unique opportunity
→ **However, most MER research emphasizes behavioral and cognitive processes rather than epilepsy's electrophysiological mechanisms**
- This review is a systematic analysis of 103 studies to identify new research opportunities

Methods

Study Selection

- Systematic review following PRISMA guidelines. Databases: PubMed, EMBASE, Google Scholar
- Search keywords: *epileptic patients, depth electrodes, Behnke-Fried, microelectrode recordings, single units, multi-unit activity, action potentials, micro contacts, seizure onset zone*
- Inclusion:
 - Human epilepsy patients
 - Depth electrodes with microelectrode contacts
- All technical articles and reviews were excluded



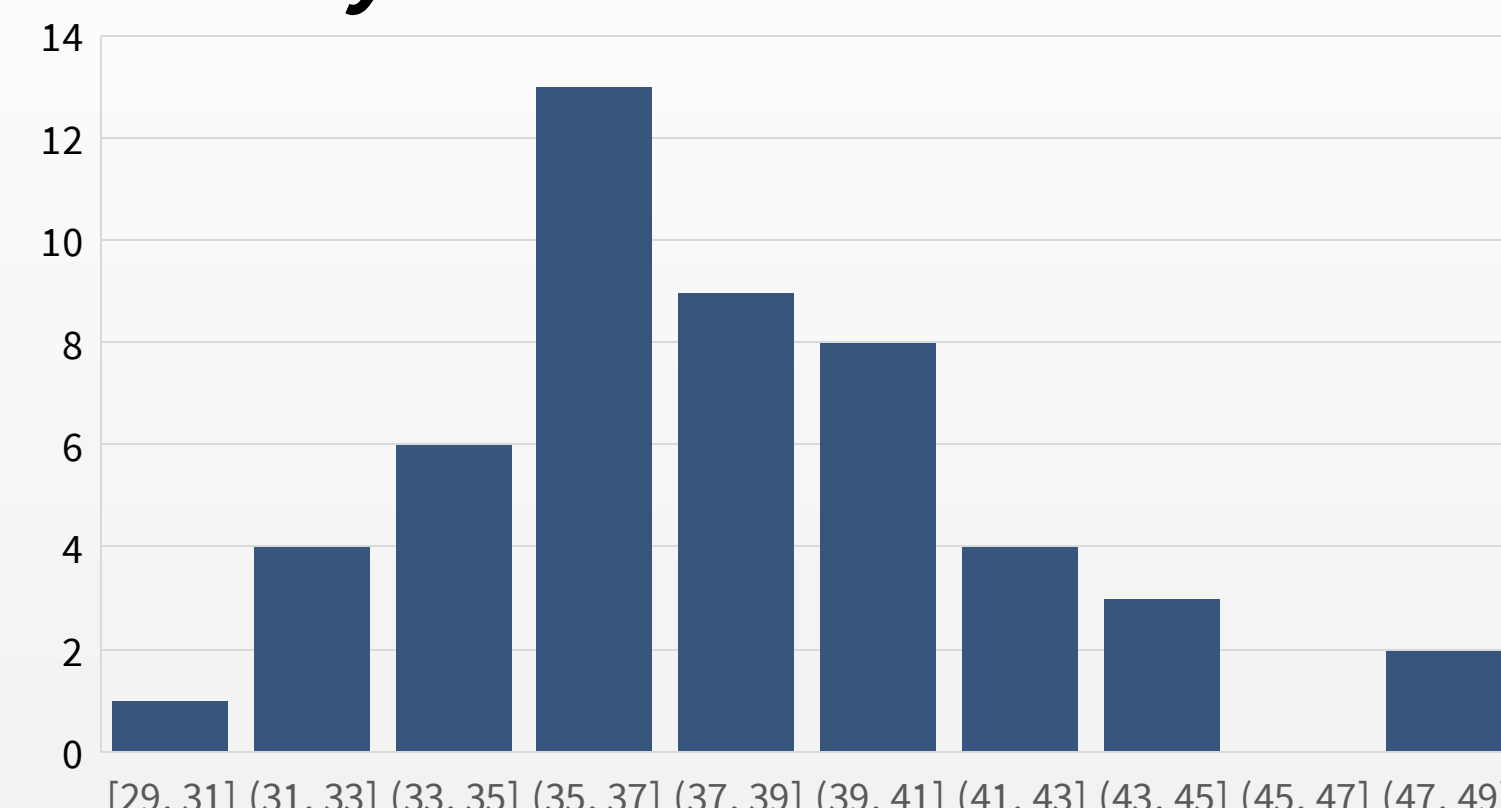
Electrode and Recording Devices



Fig. 1. Illustration of a Micro-Macro Depth Electrode with Microcontacts for single/multi-unit MER. Adapted from Dixi design; other brands use similar configurations.

- Hybrid electrodes are most commonly Behnke-Fried and Dixi Micro-Macro.
- Micro-signals require high-frequency sampling (>25 kHz) to capture action potentials.
- Most common manufacturers are Neuralynx and Blackrock Neurotech.

Study Cohorts



- Total of 1404 patients
- Average 13.6 ± 8 patients/study
- Average age: 37.87 ± 3.84 years

Fig. 2. Mean Age of study participants

Results

Count of Clinical vs Cognitive Studies

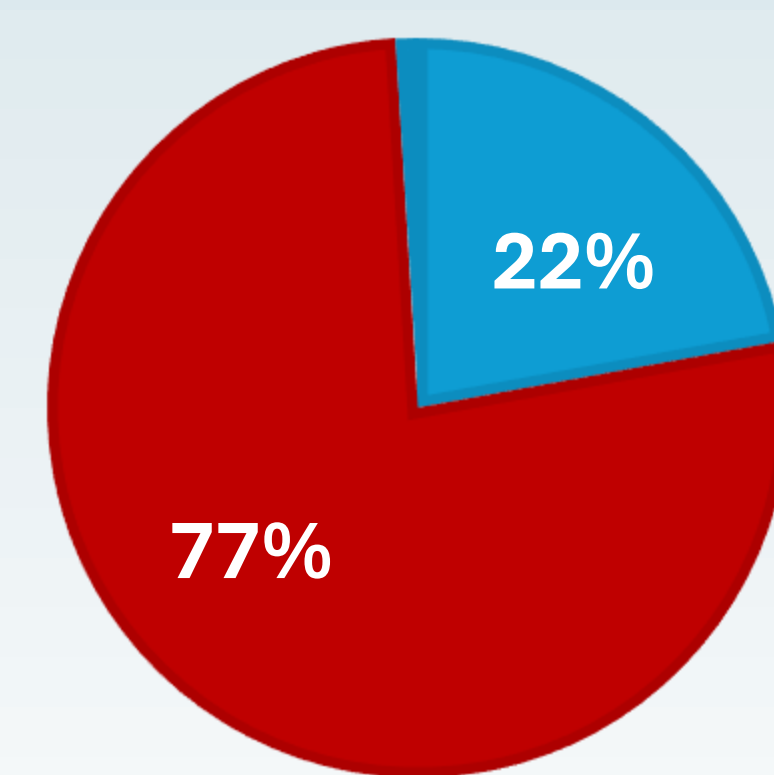


Fig. 3. Clinical vs. cognitive studies involving MERs

- Majority of MER research is cognitive
- Investigation of memory and recognition is the most common research interest
- Single/ Multi units electrophysiology during seizures is minimally described

Top 5 of Study Topic for Clinical or Cognitive Research

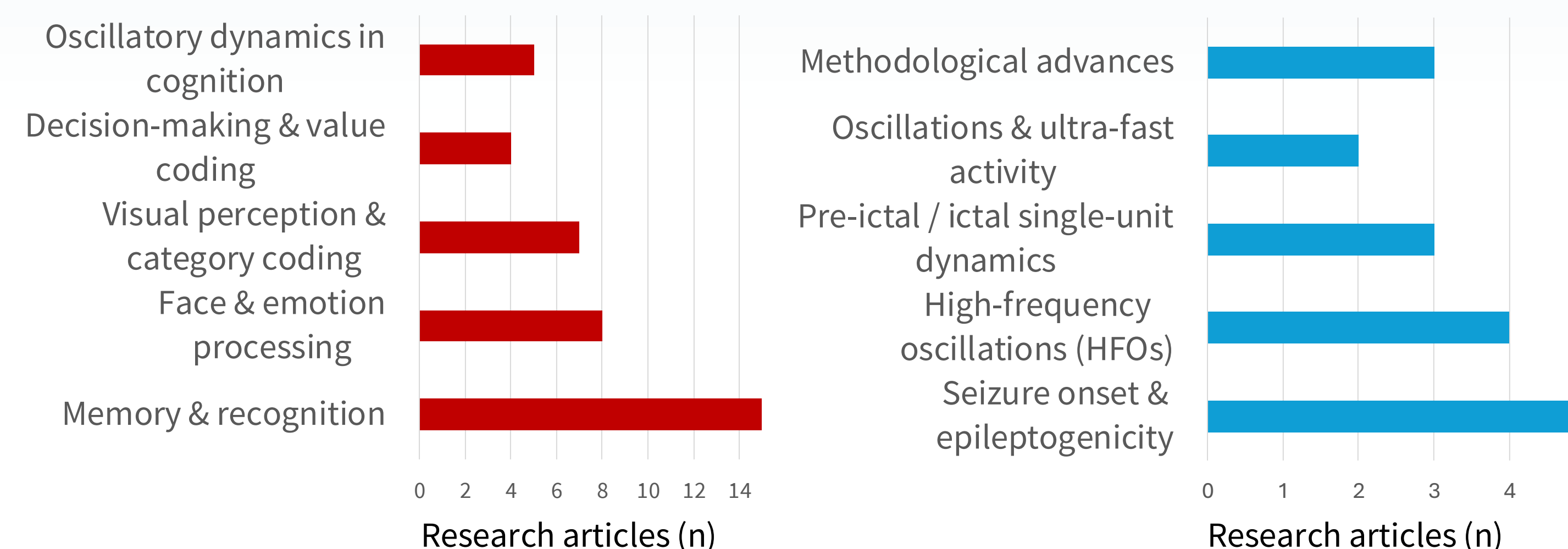
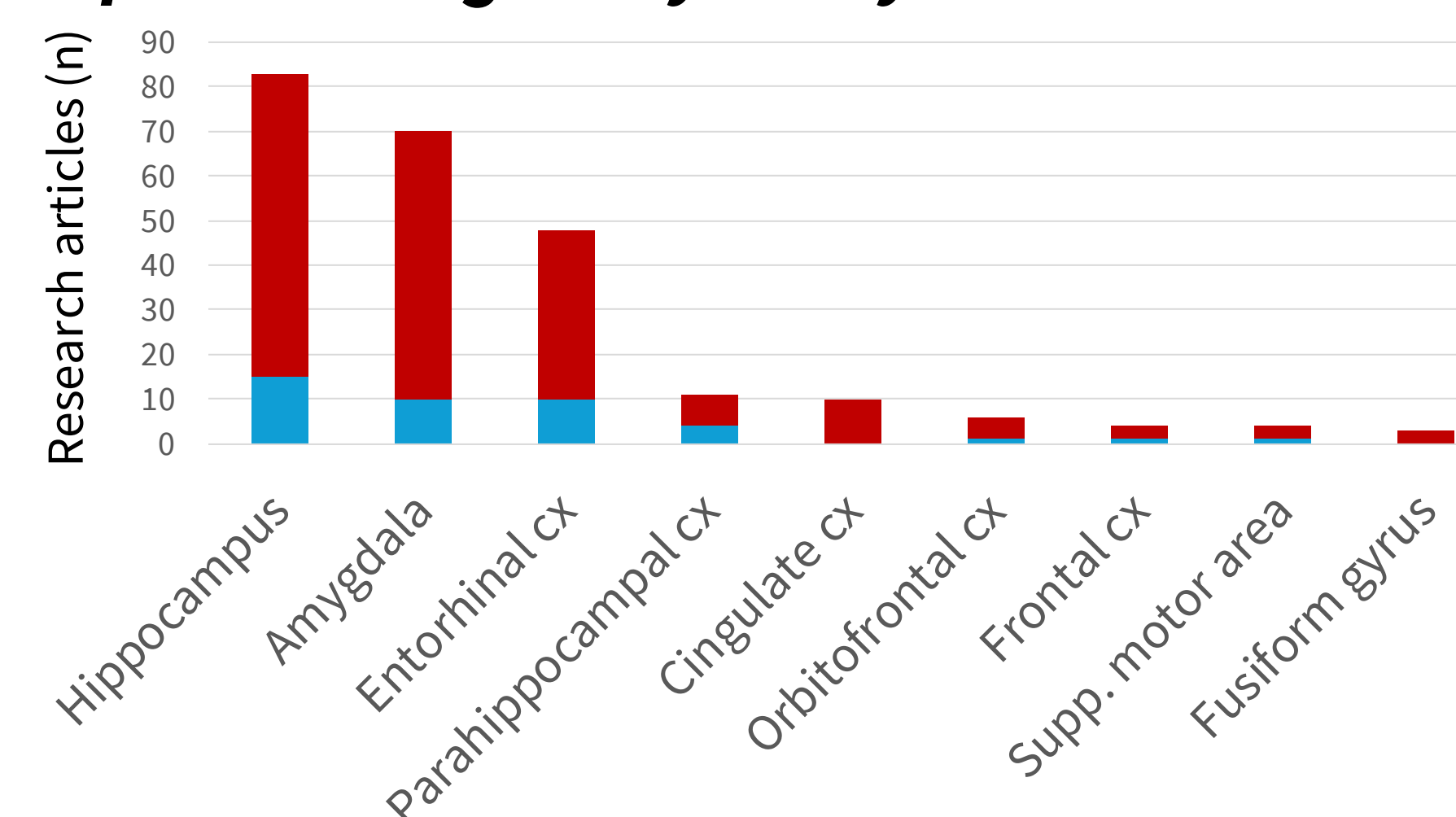


Fig. 4. Classification of MER research topics in clinical or cognitive research

Implanted Region by Study



- Mesial temporal lobe is the most frequently implanted
- Neocortex is not often investigated

Fig. 5. Number of studies in which each brain region was implanted

Units Recorded

- Across 103 studies, average of $7.26 (\pm 7.07)$ units/ electrode, $53.89 (\pm 59.63)$ units / patient
- More total units recorded and units/electrode for cognitive studies

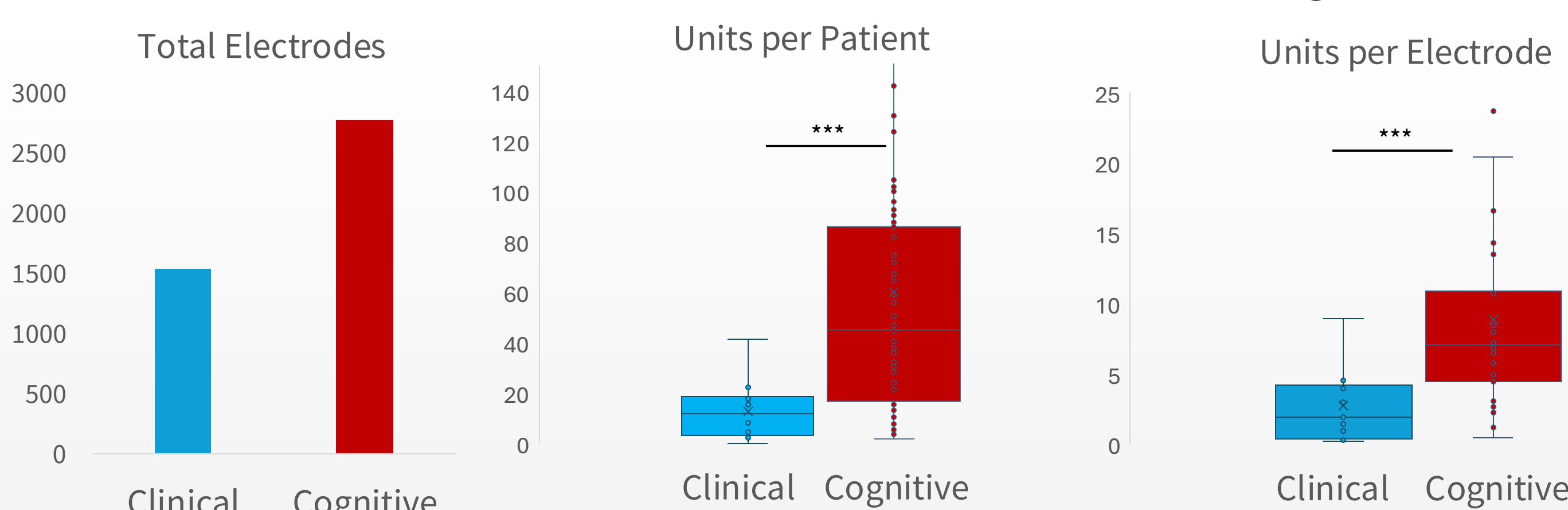
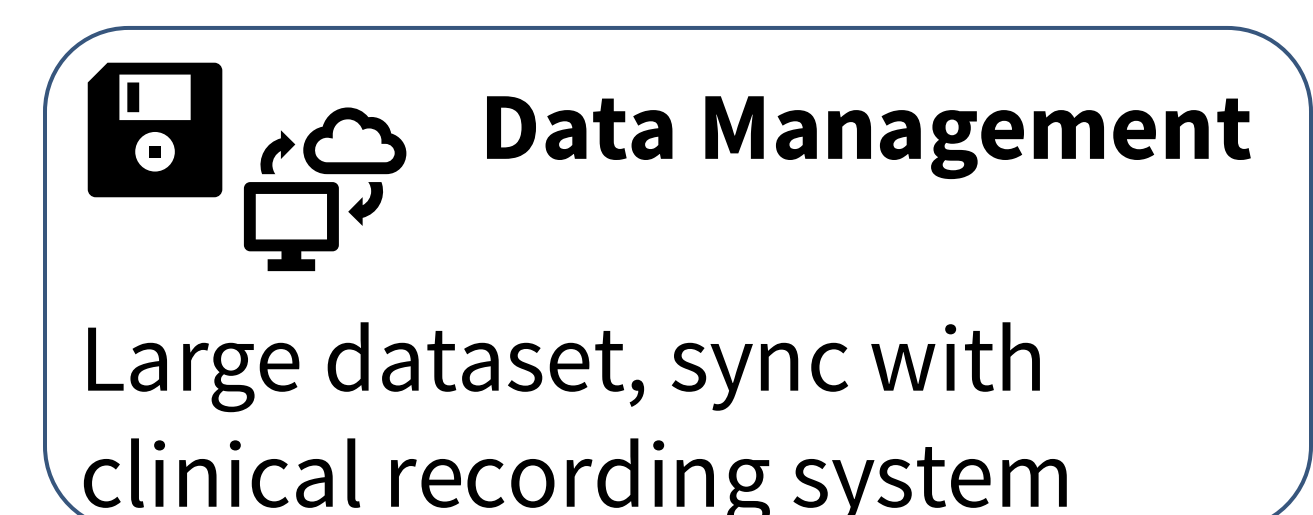
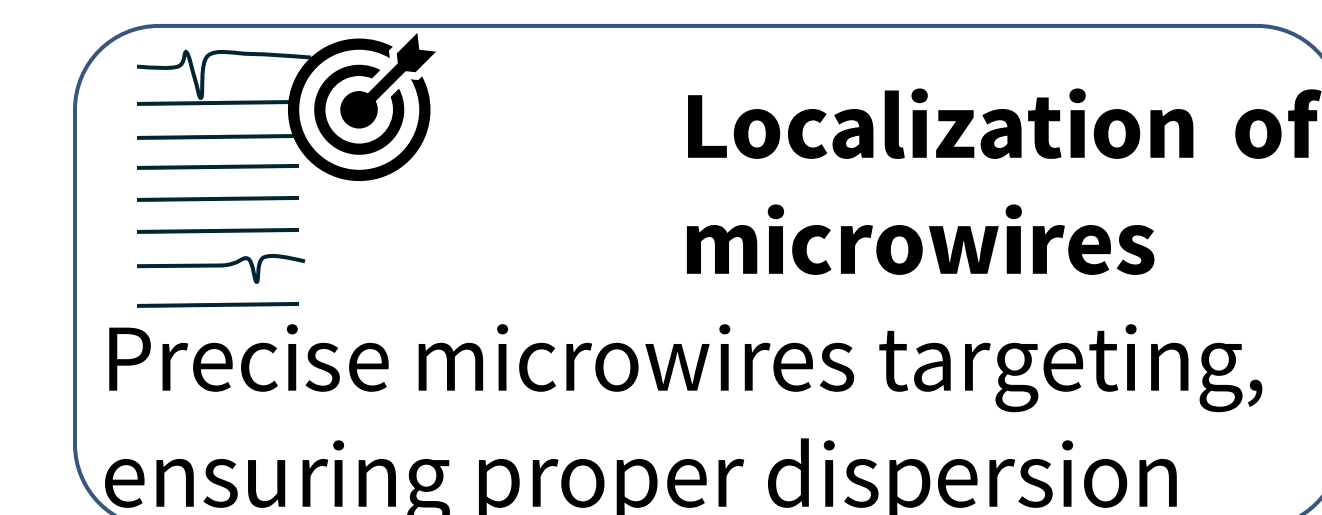
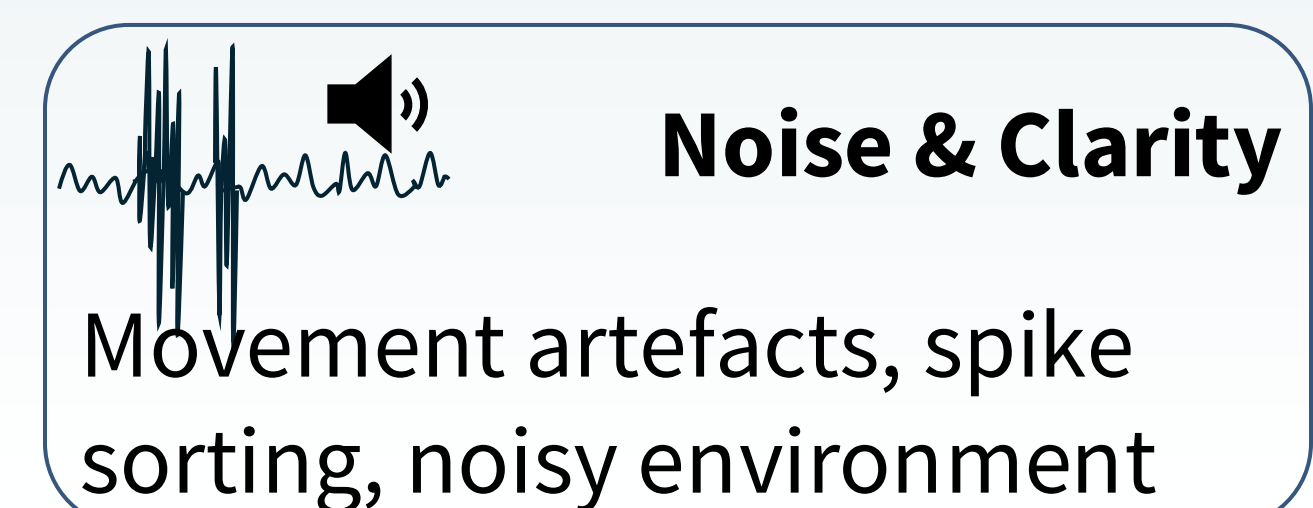
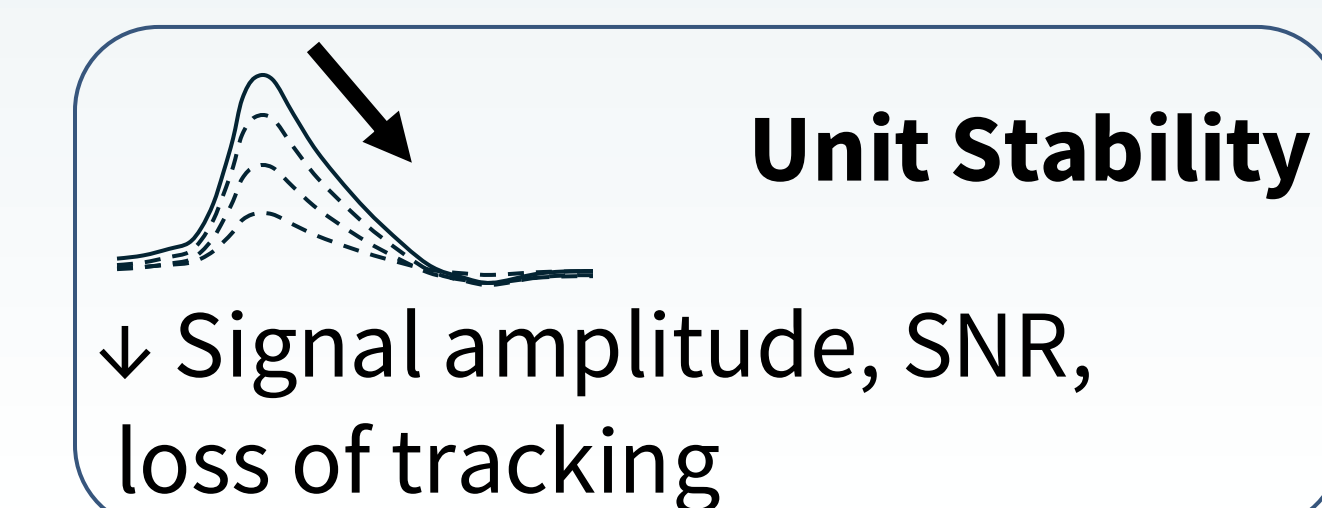


Fig. 4. Comparison of electrodes and unit recordings between clinical and cognitive studies.. Number of units per patient and units per electrode were significantly higher in cognitive studies. (*** $p < 0.001$).

Discussion

Microelectrode recordings have significantly advanced cognitive neuroscience. In contrast, clinical epilepsy research remains limited. There is significant untapped potential for clinical research using MER to advance our understanding of epilepsy.

Recording Challenges



Conclusions & Opportunities

- MER literature includes >1000 patients, mostly adult cognitive studies.
- Pediatric and clinical seizure applications remain understudied.
- Cortical microrecordings are uncommon but may advance understanding of cellular-level mechanisms in epilepsy.

Future Directions

- Use interictal MER for SOZ identification → reduce need for spontaneous seizure capture.
- Identify neuronal firing predictors of seizures → inform responsive neuromodulation.
- Study developmental differences in MER activity → reveal treatment-relevant mechanisms.

References

A detailed list of references (n=103) can be accessed via this QR code:



Acknowledgements

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