Human oscillatory activity during virtual navigation: a comparison between scalp and intracranial recordings

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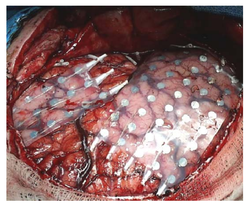
Introduction

- We used electroencephalographic (EEG) recordings to study the modulation of brain oscillations with respect to navigational behavior within a 3D environment.
- We present a novel comparison of intracranial EEG (iEEG) and scalp EEG (sEEG) data from humans performing the same task.

Previous findings:

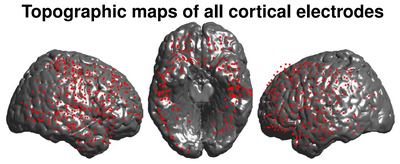
- Increased oscillatory power during virtual movement vs. standing still in both cortical (Caplan et al., 2003) and hippocampal regions (Ekstrom et al., 2005).
- Increased frontal and parieto-temporal theta oscillations at the scalp during goal-directed navigation (Nishiyama & Yamaguchi, 2001; Nishiyama et al., 2002).

Intracranial EEG



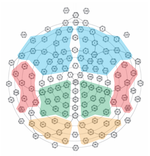
- 12 patients (ages 14 - 42) with refractory epilepsy.
- Long-term invasive monitoring to localize seizure onset for subsequent resection.
- Unique opportunity to study electrophysiology of human cognition.

Topographic maps of all cortical electrodes



	Left		Right	
	# Elec.	# Subj.	# Elec.	# Subj.
Frontal	158	7	184	9
Temporal	123	8	154	9
Parietal	34	3	67	7
Occipital	9	3	17	5

Scalp EEG



- 128-channel system from Electrical Geodesics, Inc.
- 200 MΩ high-impedance amplifier.
- Recorded at 500 Hz.

- 16 participants (8 female; ages 19-27).
- Right-handed; normal or corrected-to-normal vision.
- Two participants excluded due to insufficient data.

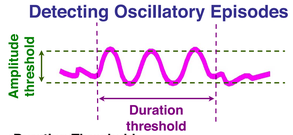
The YellowCab Task

- Participants played the role of a taxi-driver in a virtual town, looking for passengers ("Searching") and delivering them to requested destinations ("Goal-seeking") (Caplan et al., 2003; Newman et al., 2005; Ekstrom et al., 2005).

Hypotheses

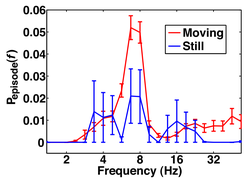
- An increase in oscillations during movement, particularly during the "Searching" phase (Caplan et al., 2003).
- Similarities between iEEG and sEEG topographies.

Analytical Methods



- **Duration Threshold**
  Avoid transients, unbiased across *f*; we use 3 cycles
- **Amplitude Threshold**
  95th%ile of estimated (1/*f*) background signal

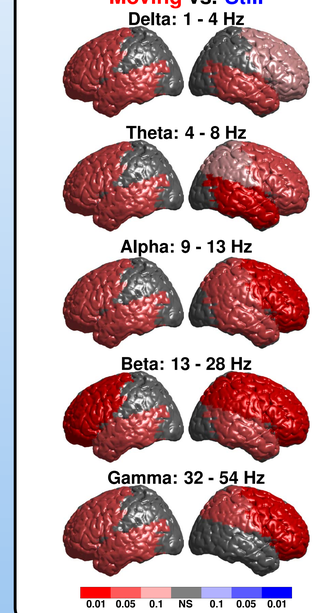
- $P_{episode}$ (Caplan et al., 2001):
  - Method of quantifying oscillatory activity
  - Indicates proportion of time that an oscillation at frequency *f* appears above background EEG activity.

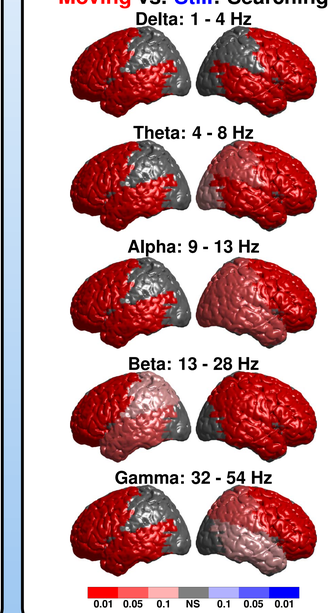


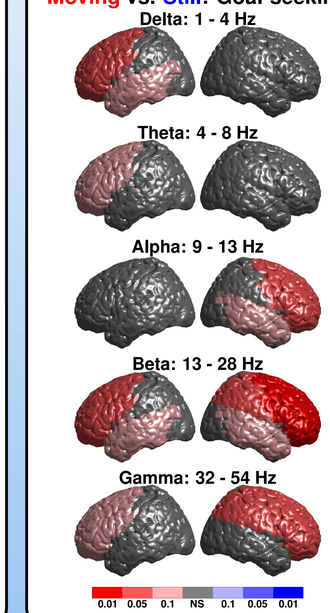
$P_{episode}$ at a right temporal electrode in an iEEG patient during the "Searching" phase.

- **Region of Interest (ROI) Analysis:**
  - Data combined across participants at each frequency band (5 bands; 24 bins; 1 - 54 Hz) and ROI (Right/Left Frontal, Parietal, Temporal, Occipital).

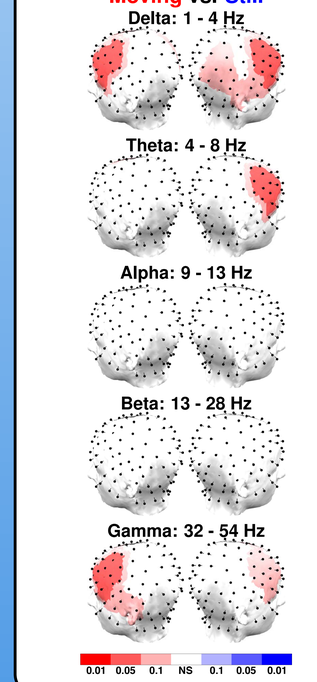
iEEG Results

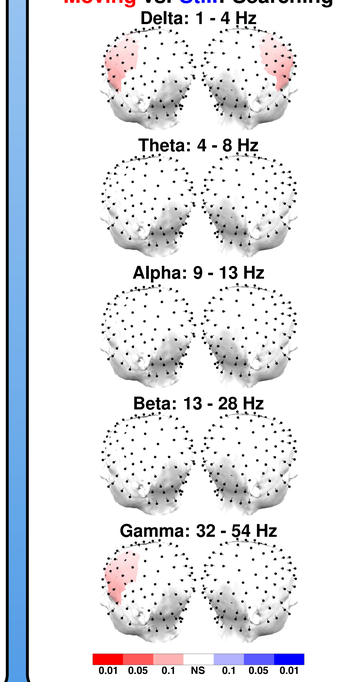


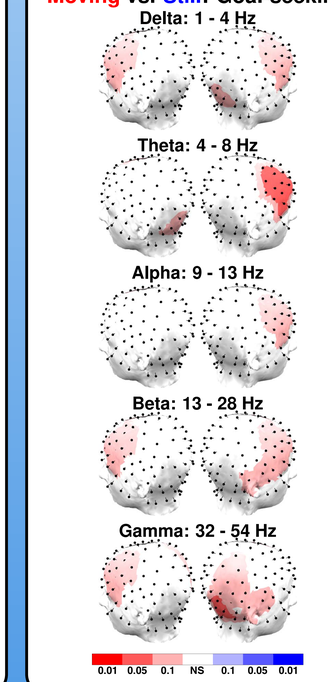




sEEG Results







Discussion

- Unidirectional increase in oscillations at both scalp and cortical surfaces during movement.
  - More powerful increase during "Searching" in iEEG.
- Difference between "Searching" and "Goal-seeking" topographies.
- There is not a perfect concordance between iEEG and sEEG topographies.
  - iEEG oscillations are often locally generated (Raghavachari et al., 2005).
  - Observable activity at the scalp requires synchronous neuronal activity.

ROI Analysis Details

For each participant:

- *P*-values (non-parametric test) at each electrode and frequency bin converted to *z*-scores.
- Average *z*-scores within each ROI.
- Average *z*-scores across frequency bins within each band for each ROI.

Across participants:

- One-sample *t*-test on mean *z*-scores for each ROI and frequency band.

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