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RPPR Final Report
as of 24-Jan-2019

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Proposal Number: 63033LS | **Agreement Number: W911NF-14-1-0173**

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Report Date: 30-Apr-2018 Date Received: 18-Jan-2019
Final Report for Period Beginning 15-Apr-2014 and Ending 31-Jan-2018
Title: The Spatiotemporal Resolution of Cognitive Signals Revealed Through High-Density uECoG Mapping
Begin Performance Period: 15-Apr-2014 **End Performance Period:** 31-Jan-2018
Report Term: 0-Other
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 0 **STEM Participants:** 1

Major Goals: The spatiotemporal resolution of the neural code that underlies attention (and other cognitive signals) is not well understood, despite a large literature that tests how these signals are modulated at the level of the single neuron. These issues have not been resolved because, until recently, it was not possible to record from large numbers of brain sites simultaneously. The goal of this grant is to fill our knowledge by testing two hypotheses. First, attentional signals can be decoded from μECoG signals in the ventrolateral prefrontal cortex (vPFC), which is cortical region that is functionally involved in auditory attention. Second, the ability of a Bayesian linear estimator to decode attentional signals depends on the spatiotemporal resolution of the μECoG-array signals.

Accomplishments: 1. designed and produced a uECoG device
2. implanted uECoG device in PFC of rhesus monkey
3. recorded successfully uECoG signals from device
4. Demonstrated that both sensory and cognitive (i.e., choice dependent) signals can be read out from uECoG signals.
5. Our modular system shows stable long-term recordings (~1 year) as the decoding accuracies are not varying much across the implantation period.
6. Determined that sufficient coverage and recording resolution is needed for accurate "decode".

Training Opportunities: Nothing to Report

Results Dissemination: 1. Abstract at 2018 Society for Neuroscience Meeting:Chiang, J., Lee, J., Williams, A. J., Cohen, Y. E. & Viventi, J. in Neuroscience 2018 Vol. Program No. 431.21 Online (Society for Neuroscience, San Diego, CA, 2018).

2. Preparing manuscript for submission in early 2019 to IEEE journal.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

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Participant: yale cohen
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

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Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Technician
Participant: harry shirley
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: chia han chiang
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

CONFERENCE PAPERS:

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Conference Name: 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society
Date Received: 25-Aug-2016 Conference Date: 27-Aug-2014 Date Published: 27-Aug-2014
Conference Location: chicago, IL
Paper Title: A low-cost, multiplexed electrophysiology system for chronic uECoG recordings in rodents
Authors: Wang, J., Trumpis, M., Insanally, M., Froemke, R., & Viventi, J.
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: 7th Annual International IEEE EMBS Conference on Neural Engineering
Date Received: 07-Mar-2017 Conference Date: 22-Apr-2015 Date Published: 24-Apr-2015
Conference Location: Montpellier, France
Paper Title: A low-cost, 61-channel µECoG array for use in rodents.
Authors: Woods, V., Wang, C., Bossi, S., Insanally, M., Trumpis, M., Froemke, R., & Viventi, J.
Acknowledged Federal Support: **Y**

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Conference Name: 8th Annual International Conference of the IEEE Engineering in Medicine and Biology Society
Date Received: 29-Aug-2016 Conference Date: 16-Aug-2016 Date Published: 16-Aug-2016
Conference Location: Orlando, FL
Paper Title: In vitro Assessment of Long-Term Reliability of Low-Cost ?ECoG Arrays
Authors: Kay Palopoli-Trojani Virginia Woods, Chia-Han Chiang, Michael Trumpis, and Jonathan Viventi
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Society for Neuroscience, 2018
Date Received: 16-Jan-2019 Conference Date: 05-Nov-2018 Date Published: 03-Nov-2018
Conference Location: San Diego, CA
Paper Title: A modular high-density 294 channels uECoG system on macaque vlPFC for auditory cognitive decoding.
Authors: C. CHIANG, J. LEE, C. WANG, A. J. WILLIAMS, Y. E. COHEN, J. VIVENTI
Acknowledged Federal Support: **Y**

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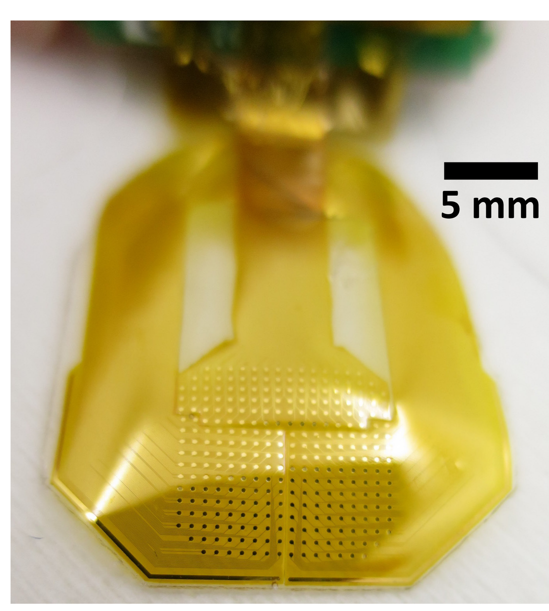
Introduction

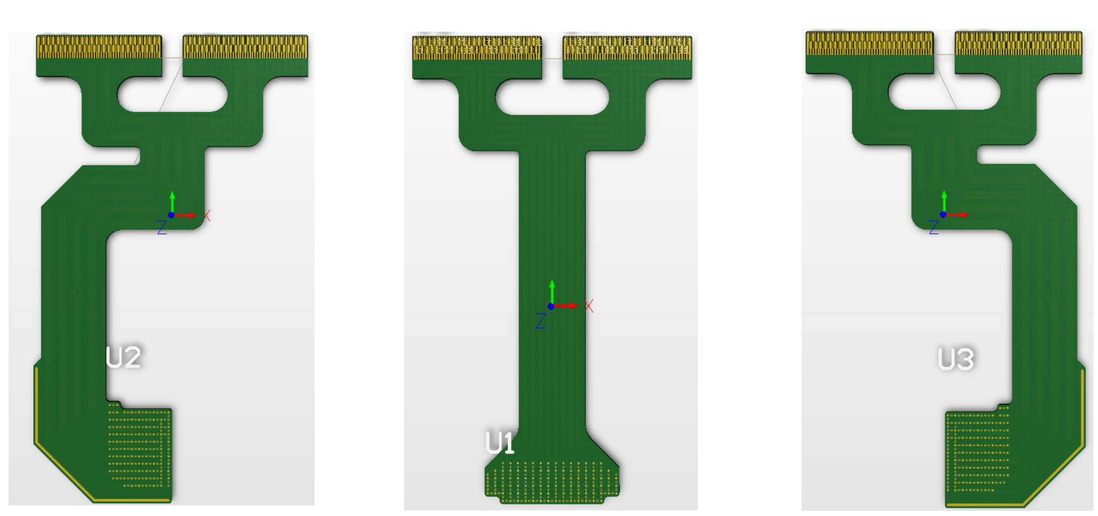
- Detecting and discriminating auditory stimuli is a complex neurocomputational problem because the stimuli of interest in the real world change simultaneously along multiple dimensions and are often mixed together with other environmental stimuli.
- It is not well understood how the brain transforms a mixture of acoustic stimuli into distinct perceptual representations.
- Auditory perceptual decisions are believed to be mediated by the ventral auditory pathway, which includes the ventrolateral prefrontal cortex (vlPFC) at its apex.
- However, the spatiotemporal resolution of the neuronal code that underlies perception and cognition in vlPFC is still unclear; and until recently, it was not possible to record from large numbers of brain sites simultaneously.
- In this work, we developed a modular, high-resolution, electrode array with long-term viability to study the information that could be decoded from vlPFC micro-electrocorticographic (μECoG) signals during an auditory-detection task.

Electrode Design

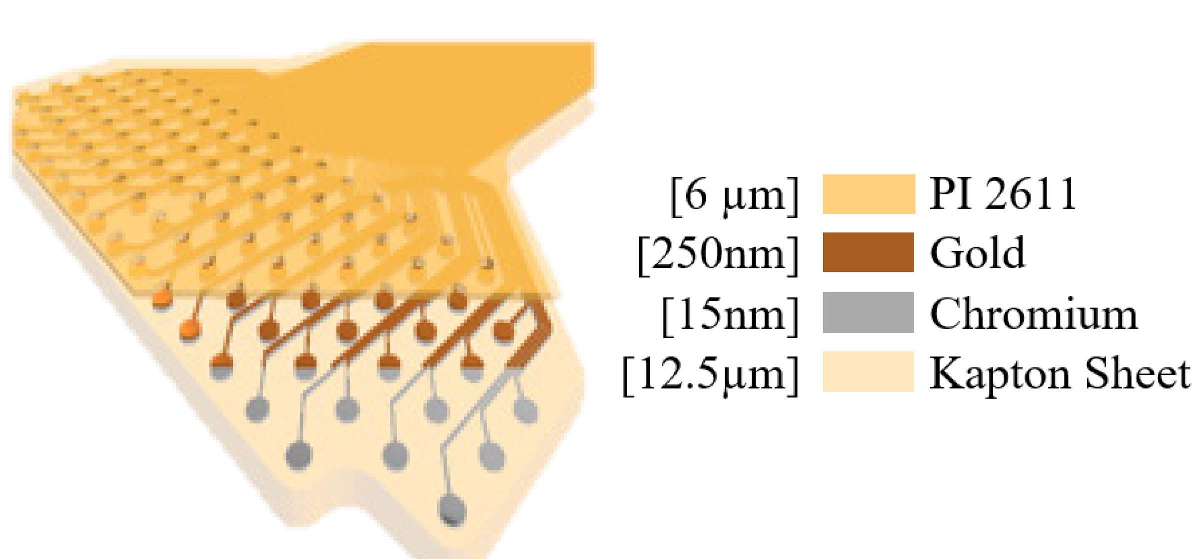
- 3 subarrays molded together
- 294 channels total
- 17 x 18 grid
- 610 μm pitch
- 229 μm (dia.) pad
- 10.4 x 11 mm^2 sensing area
- ~30μm thick total
- High density ZIF connector



Modular design

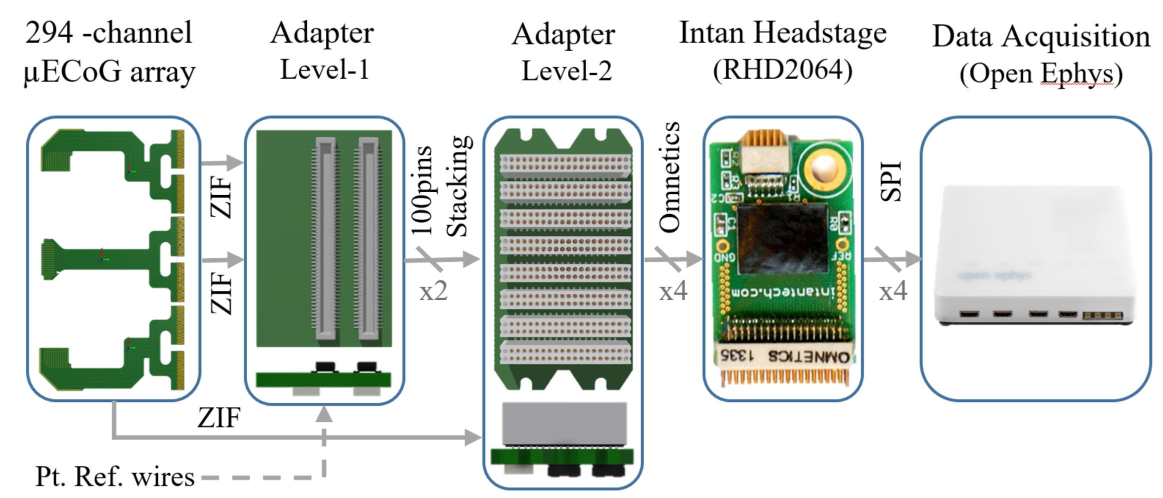


Stack-up

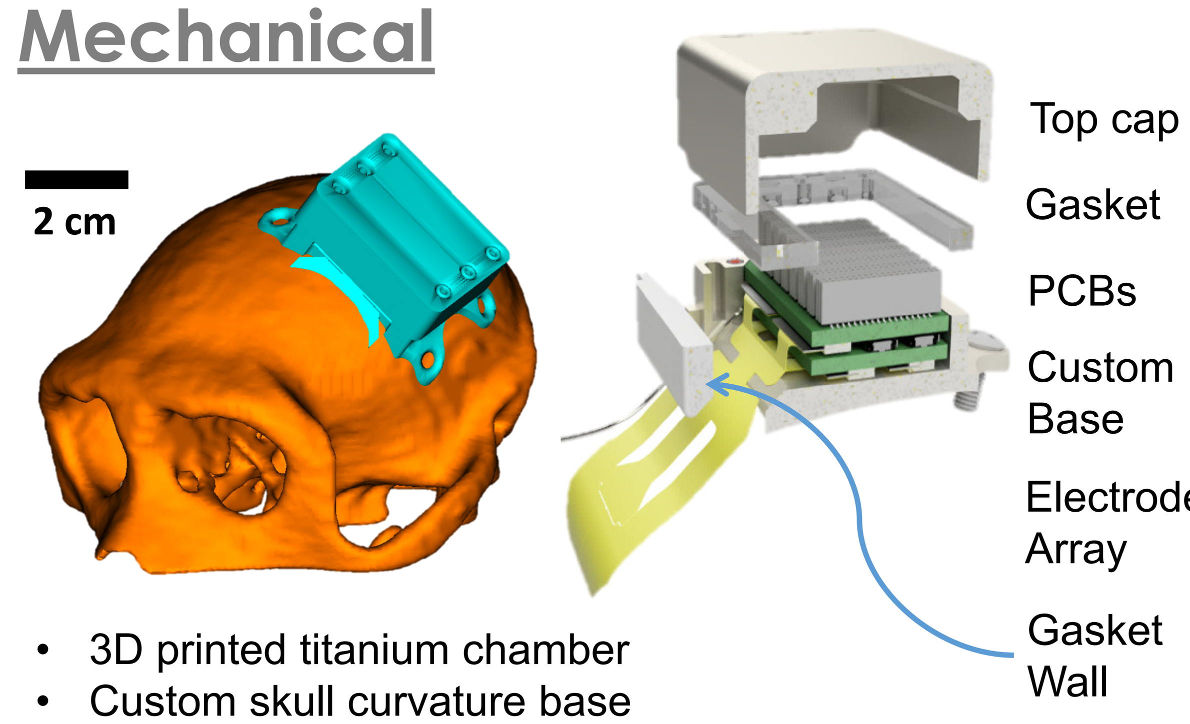


System Design

Electrical



Mechanical

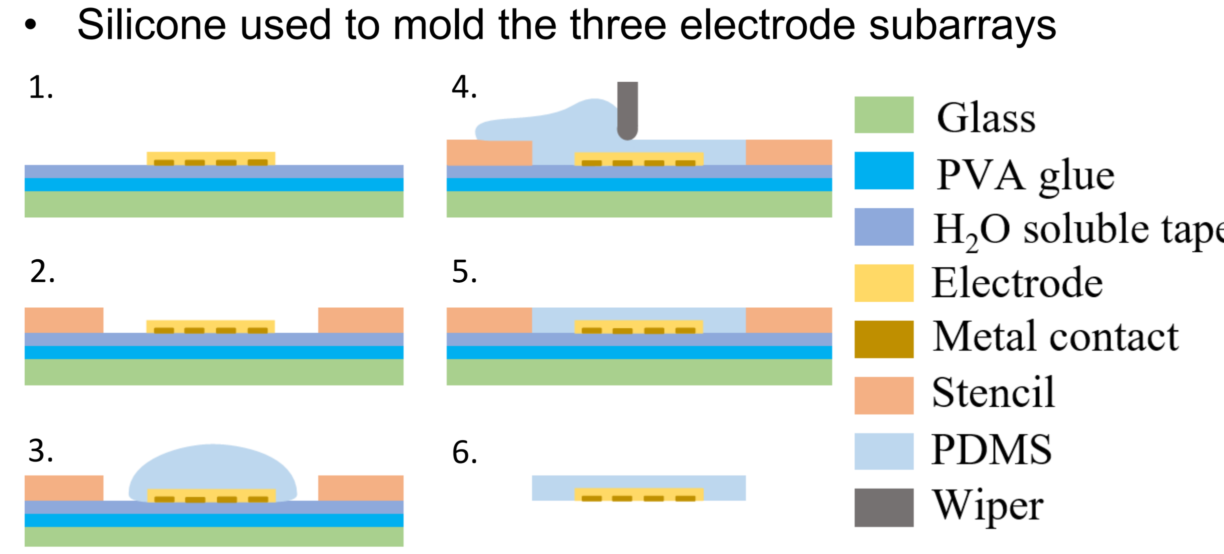


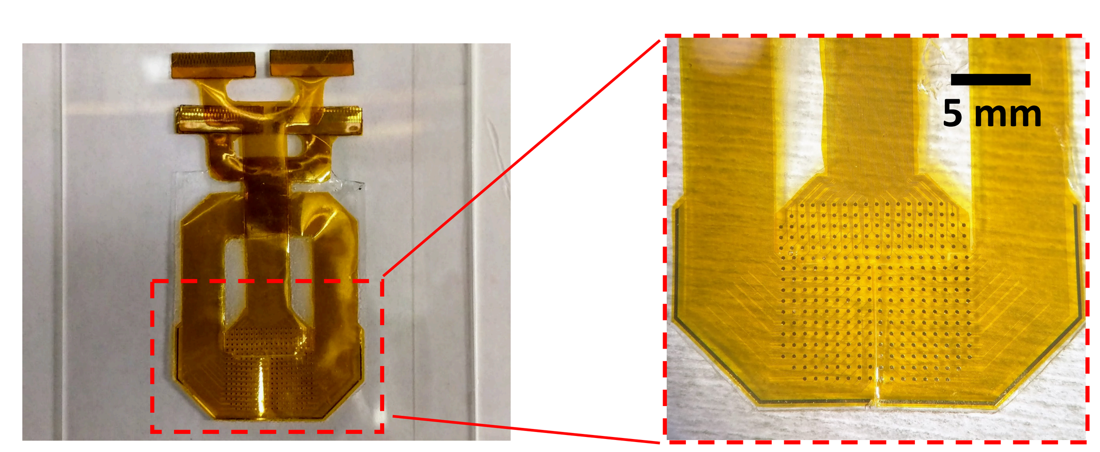
- 3D printed titanium chamber
- Custom skull curvature base
- Overall size: 35mm x 27mm x 18mm
- Weight: 76g

Molding

Electrode Molding

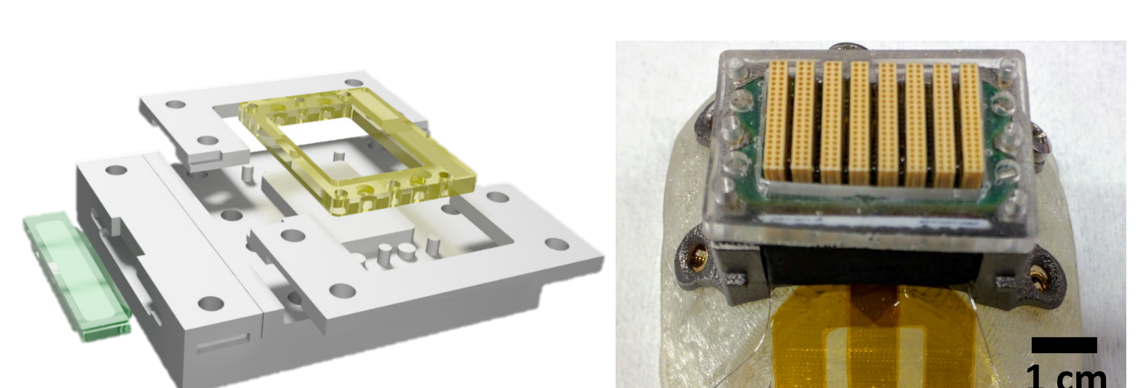
- Silicone used to mold the three electrode subarrays





Gasket Molding

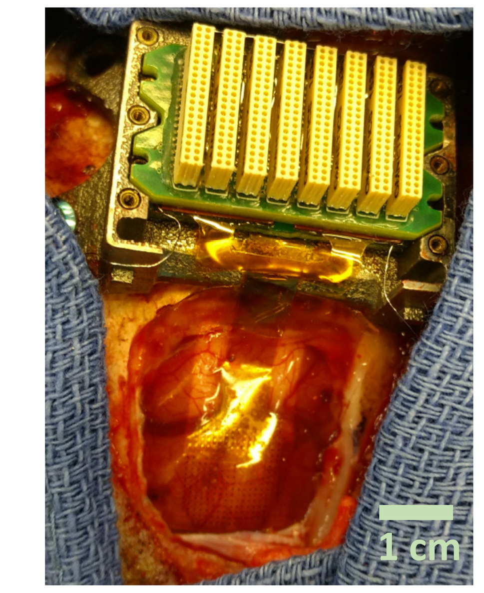
- To make the chamber water tight, we molded a gasket with PDMS and the electrode entrance wall with Sugru



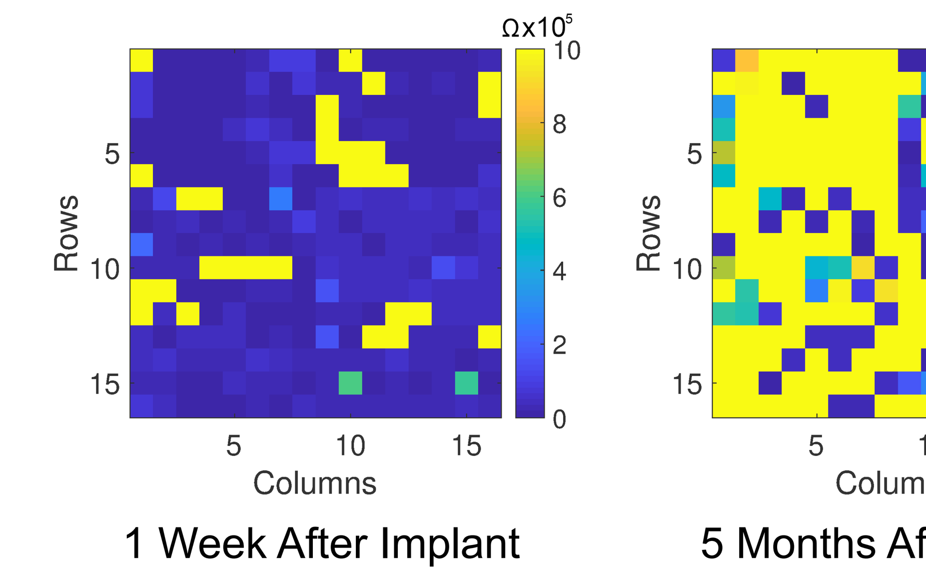
NHP Experiment

Subdural implant over **vlPFC**.

1. A monkey participated in a "cocktail-party" task that required him to detect a target vocalization that was embedded in a background chorus. Task difficulty was titrated by varying the sound-level ratio between the target and the background chorus (TCr).
2. We recorded μECoG signals while the monkey participated in the task.



Impedance over 1



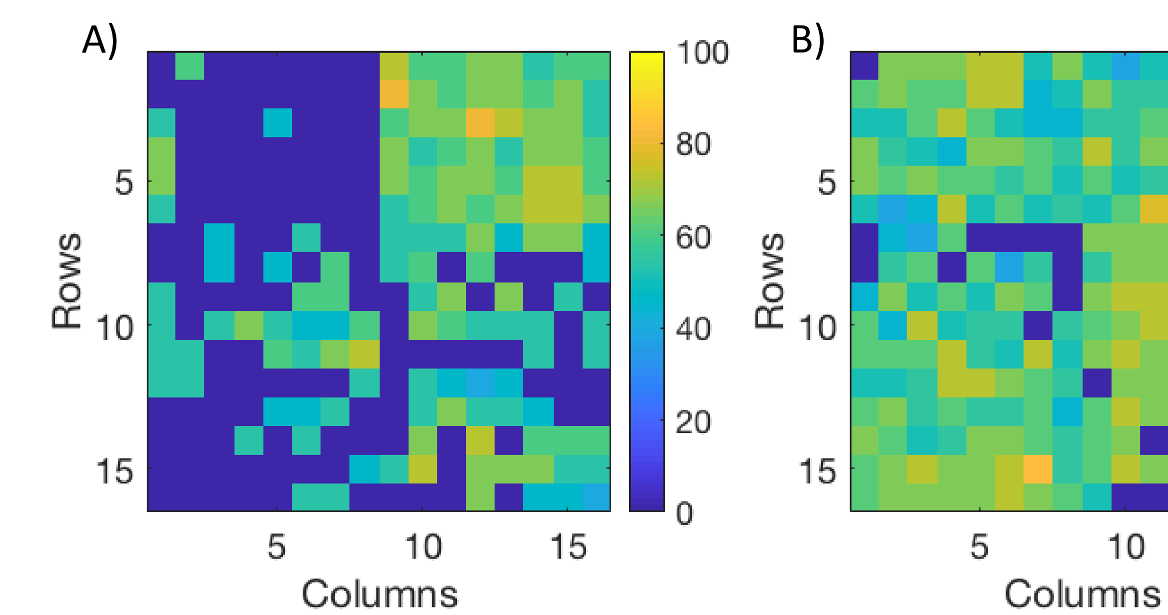
Signal Processing

Signal Processing Flow for SVM*

1. Select features (mean, variance).
2. Calculate single-channel classification accuracy using SVM (LibSVM in the MATLAB platform)
   a. Grid-search to optimize LibSVM parameters with N-fold cross-validation
3. Pick channels corresponding to top 20th percentile.
4. Run cross-validated SVM classification for 1, 2, 4, …, N channels.

*SVM: Support Vector Machine

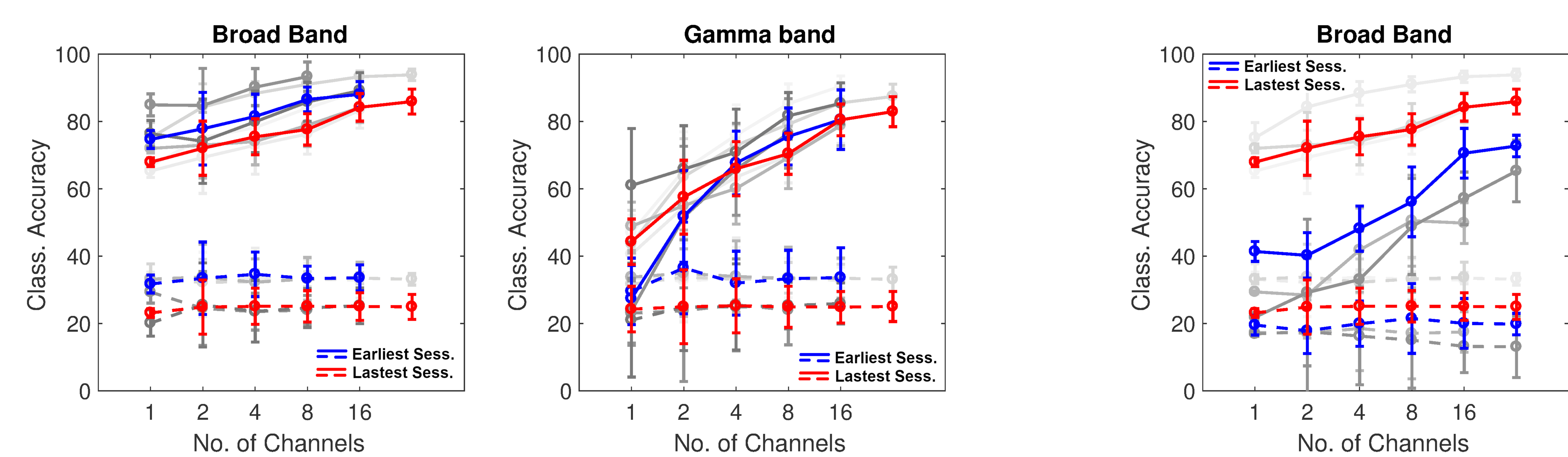
Single-Channel Behav



Decoding Results

Behavior Decoding (Hits v. Misses)

Sensory Decoding (



1. Solid lines: decode capacity; dotted lines: bootstrap null distribution; each set is decode from a single recording sess session; data in red from last recording session. Data in grey are from other sessions; the darker the shading the mo
2. Behavior decoding states: (a) Hits, (b) Misses, (c) False Alarm, and (d) Correct Rejection.
3. Sensory decoding states: 5 target-to-chorus ratios ranging from 60% to 80%.
4. Classification accuracy both for behavioral outcomes and TCr improved significantly as the number of decoding char
5. Higher frequency bands, such as gamma band, showed the most noticeable enhancement in decoding accuracy, rel

Discussion / Summary

- μECoG signals in vlPFC code both behavioral outcomes and stimulus parameters.
- Sufficient coverage and recording resolution is needed:
  - Individual channels varied significantly in their ability to decode various behavioral parameters (e.g., hits versus misses).
  - For those channels that performed better than chance, as we increased the number of channels, decoding performance improved. This improvement was seen across a variety of neural frequency bands.

Acknow

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